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A NEW ODONTOGRAPH.

By HUGO BILGRAM, M.E.

Read before the Franklin Institute, November 16, 1881.

An odontograph can be based on the fact that if the shape of the teeth of a rack consists of two congruent branches, corresponding points of which meet tangentially in the pitch line, any two gear wheels correctly gearing into this rack will also correctly gear with one another.

The construction and mode of application of this odontograph is as follows: To a bar, *A*, Fig. 1, representing a rack, one edge of which (the pitch line) is carefully straightened, is attached a template, *T*, of a tooth carefully filed so that each side consists of two equal curves meeting exactly in the pitch line. The mode of attachment is such that a space, *S*, is left between the bar and that part of the template representing the tooth. To delineate the form of teeth of a required gear wheel, it is only necessary to procure a circular plate, *B*, or a portion of such a plate, of a diameter equal to the pitch diameter of the required gear wheel, and fasten to it a piece of sheet metal, *t*, upon which the tooth can be constructed by what was probably the first method ever employed to design properly shaped gear wheels, namely,

by rolling the disc *B* on the bar *A* (or *vice versa*) and marking with a fine scriber the tooth, *T*, in a number of positions on the template sheet, *t*. (See Fig. 2.) A band of very thin steel, one end fastened to the rack, the other to the wheel-plate, may serve as a means to pre-

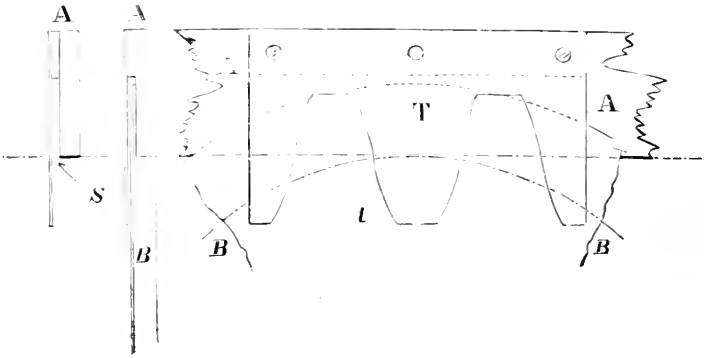

Fig. 1.

vent slipping. The form thus delineated, or enveloped, can then be cut and filed to complete the secondary template, *t*. It is advisable to have this latter template extend to the centre of the plate *B*, for the reception of a concentrical hole, suitable to its future use, to insure radial position and proper distance from the centre of the wheel.

If the gear wheels made in this way are required to have clearance or play, the width of the template tooth, *T*, should be greater than one-half the pitch, its height above the pitch line greater, and its depth below it less than one-half the total height of the tooth.

The template *T*, as shown in the drawing, contains the sides of the adjacent teeth. By its use, the secondary template will have two teeth, one of which may be employed for marking the tooth to be laid out, the other one will serve as a means of checking the distance of teeth.

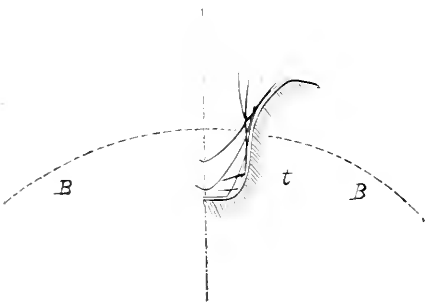

Fig. 2.

This odontograph can be employed for the construction of epicycloidal as well as involute teeth, or for any intermediate form. For epicycloidal teeth, the form of the original template must consist of two cycloids developed by the roll-

ing of a circle on the pitch line of the rack. The diameter of this rolling circle, as is well known, should be equal to the pitch radius of the smallest pinion likely to be required for the set of gears. For involute teeth, the tooth of the rack should be defined by straight lines, of an angle of about 75°. But also any other suitable form may be used, provided it is within certain conditions. In cast bevel wheels, for instance, purely cycloidal gears have the one objection of being without "draft" near the pitch cone, while involute teeth are objectionable owing to their less regular wear compared with cycloidal gears. To meet this case, the original template may be made almost identical with the cycloidal form (see dotted line of Fig. 3) but slightly deviating near the pitch line to produce "draft."

The proper shaping of the teeth of gear wheels of irregular shapes, for instance of elliptical wheels, can likewise be accomplished, for this odontograph makes such teeth theoretically correct. For internal gear wheels, the described method is equally applicable, as it can be shown that for interchangeable gear forms, the inverted gear must be an exact counterpart of an external or spur wheel of the same size, excepting as regards the allowance for clearance. Respecting internal gear, however, another explanation is in order, namely, as regards the fillet described by this odontograph at the base of the teeth. Owing to this fillet, the points of the inverted or annular gear-wheel teeth would become rounded off by the mere inversion of an equal sized spur wheel described by this odontograph, which is equivalent to a shortening of the teeth and a consequent reduction of the number of teeth in gear at the same time. This number is, however, generally abundant with internal gear, and the reduction alluded to unimportant. But if it is considered an objection, the remedy consists in making the template tooth of the describing rack very long for *both* the internal and the inverted gear and, after the construction of the form, reducing the height of the teeth to suit.

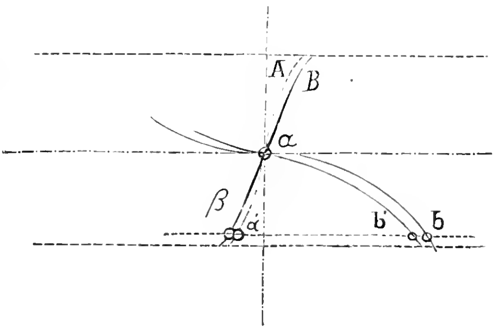

Fig. 3.

The herewith proposed mode of laying out gear wheels thus includes almost every imaginable modification pertaining to the subject.

The advantages in favor of this odontograph, for practical use, may be said to be as follows:

1. The forms obtained by it are not only approximately but theoretically correct, provided the original template is properly made, and by the use of auxiliary templates any desirable degree of accuracy can be obtained in this respect.

2. The degree of inaccuracy in workmanship is materially reduced as compared with teeth laid out by circular arcs or their intersections, by reason of the difficulty attending the placing of the centre point of the compasses in the exact location.

3. The handling and application requires no great intelligence, but simply skill and care.

4. In the original selection of form, one is not confined to the cycloidal or to the involute curve; for, if it is desired, an intermediate of any grade between the two can be selected.

5. On the base of the teeth described by this odontograph a fillet will be noticed, which increases the strength of the teeth. This is the largest fillet admissible if the gear wheel is ever required to gear into a rack, being the prolate involute of the corner-point of the rack tooth. Only, if the gear wheel is wanted for an internal gearing, the fillet must be reduced, unless the above-mentioned rounding of the points of the teeth of the inverted gear is not objected to. No other odontograph possesses this feature.

The principle of this odontograph may even be used in the construction of a gear-cutting machine, to give theoretically correct shapes. Suppose a shaping machine, provided with a tool of the shape of a rack tooth, would, by the cross-feed, produce a simultaneous rotation of the wheel to be cut, or rather corrected, say by means of a thin steel band running over a cylinder of the diameter of the pitch-circle of the wheel. This operation is identical with the above-described application of the odontograph. The same tool will give the proper form to all wheels, large or small, of the same set. This plan would even be applicable to the cutting of theoretically correct bevel wheels, by cutting only one side of a tooth at one time, especially if the involute form of teeth is adopted. For practical reasons, however, it is doubtful whether such machines would be commercially successful.

THE THEORY.

In order to prove the assertion which forms the base for the foregoing, the conditions should first be well understood which make a set of gear wheels interchangeable, *i. e.*, which make it possible that any two of them will correctly gear into one another. Two wheels gear correctly, if the velocity is transmitted precisely as regular as it would be by simple contact (without slip) of two true cylinders.

It is well known that if only one pair of wheels are to be made, the tooth-form of one of the wheels is, within certain limits, arbitrary, and the corresponding tooth-form of the other wheel may be obtained by a rolling of the pitch-circles and making the tooth of one wheel describe that of the other. If the pair of wheels thus constructed are in operation with their centres in fixed positions, it will be noticed

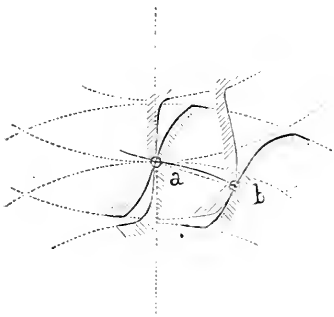

Fig. 4.

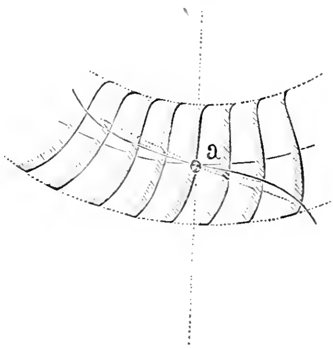

Fig. 5.

that as one tooth pushes the other one forward, the point of contact is continually changing and, if followed, is found to describe a continuous curve, the "path of contact." If the motion is arrested at any point (see Fig. 4) and a line drawn connecting the point of contact of the teeth, *b*, with the point of contact of the pitch lines, *a*, this line will be found to be normal (at right angles) to the curves of *both* teeth in the point *b*. This is the well-known condition of correctly gearing tooth-forms and, in fact, a necessary result of the manner in which the form of one tooth has been developed by the other; for at the moment when the point *b* of the second gear was developed by the rolling, the relative centre of motion was in the point *a*.

The line *a b* being a normal to the curves of both teeth, it is certainly a normal to each of those curves individually, and therefore it

is possible to construct the path of contact solely from the originally adopted tooth-form of the first wheel, before the second wheel has been constructed or even contemplated. The proceeding for accomplishing this purpose is as follows: Draw the original tooth in a number of successive positions, and from the intended point of pitch-contact, *a* (Fig. 5), normal lines to these curves. The line connecting the roots of these normals is the sought curve.

From the preceding, these conclusions can be drawn:

1. The "path of contact" of any gear wheel, when in gear, depends solely on its own tooth-form and is independent of the size of its mate, provided the mate gears correctly. We can, therefore, speak, as it were, of the "path of contact" of a single wheel.

2. Any one of a number of wheels made to gear with an original wheel of arbitrary tooth-form will possess a "path of contact" which is the exact "inversion" of that of the original wheel, namely, the inside branch of the secondary wheel will exactly coincide with the outside branch of the original wheel and *vice versa*.

3. Any wheel not obtained by the rolling of the original wheel, whose "path of contact," however, coincides with the "inversion" of that of the original wheel, will correctly gear into the latter. This expresses the condition of correct gearing.

4. Two or more wheels, all of which gear correctly with one original wheel, will, as a rule, not gear with one another, because the "path of contact" of the one is not necessarily the "inversion" of that of the other though they are congruent. But if this should happen to be the case, namely, if both branches, inside and outside, of the "path of contact" would exactly coincide with each other, all secondary wheels would gear with one another. This constitutes the condition for interchangeable gear wheels, and a few additional words will complete the proof for the correctness of the original assertion upon which the construction of the odontograph is based.

Supposing the original gear wheel would have been one of an infinite radius, a rack, the preceding contemplations and deductions would be equally applicable. Considering the mode of constructing the "path of contact," it is plain that if one rack is the "inversion" of another (*i. e.*, if the teeth of one rack exactly fit the spaces of the other), its "path of contact" is likewise the "inversion" of that of the other; and if any two gear wheels are made, one of which to gear with the one rack and the other to gear with the other rack, both

these gear wheels will correctly gear with one another; and if, further, one rack is made to coincide with its own inversion, *i. e.*, if it answers the condition expressed at the beginning, all wheels gearing into it possess equal and inversible "paths of contact" and will, therefore, gear with one another.

The introduction of the "path of contact" (instead of the rolling curves) as a base for the theory of gear wheels materially facilitates the study of their action. A few instances in this respect are herewith presented.

General Remarks.

The two principal systems of interchangeable gear wheels now in use are the cycloidal and involute forms. The "path of contact" of

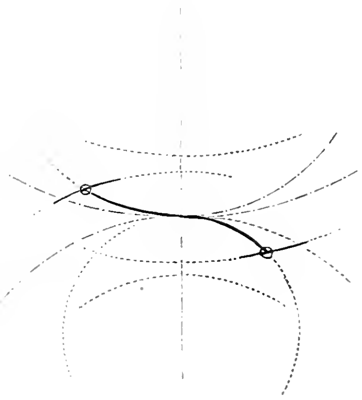

Fig. 6.

Fig. 7.

the former is identical with the rolling circles by which the cycloids are evolved (see Fig. 6), while that of the latter is contained in the right line passing between and touching both evolute circles (Fig. 7).

The well-known fact that involute wheels will gear correctly, even if the distance of centres is slightly changed, can thus readily be accounted for. The "paths of contact" being straight lines, it is not necessary to locate the centres of the wheels at a precise distance to make the paths of both wheels coincide.

By means of the "path of contact" (no matter whether the system be cycloidal, involute or any other form), it is easy to find that point of one tooth that will come in contact with a given point of the other tooth. For instance, the point *d* (Fig. 8) of the tooth *A* will come in

contact with the other tooth, *B*, the moment when, during its circular motion, it passes the "path" at *b*, and it is easy to find the point *e* of the tooth *B* which, in course of its motion, will likewise pass through the "path" at *b*. Of these two corresponding points, *d* and *e*, the for-

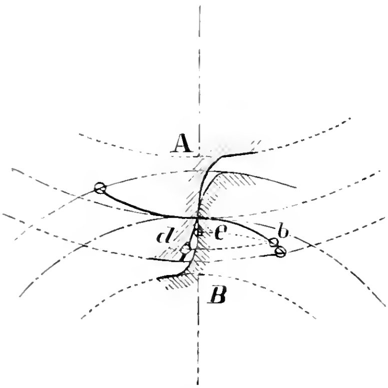

Fig. 8.

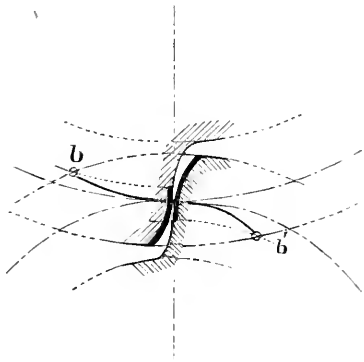

Fig. 9.

mer (of the *face* of the tooth *A*) has a greater distance from the pitch circle than the latter, of the *flank* of the tooth *B*. The fact is that all points of the face, from the pitch-circle to the point, will successively come in operation, while only a portion of the flank is made use of. The lowest useful point of the flank is that which comes in contact with the farthest end of the face of the gearing tooth, and can easily be found, as shown before. Thus, in Fig. 9, those portions of the teeth that come in actual working contact are marked by heavy lines. In the same figure, the points *b* and *b′* limit the length of the "path of contact."

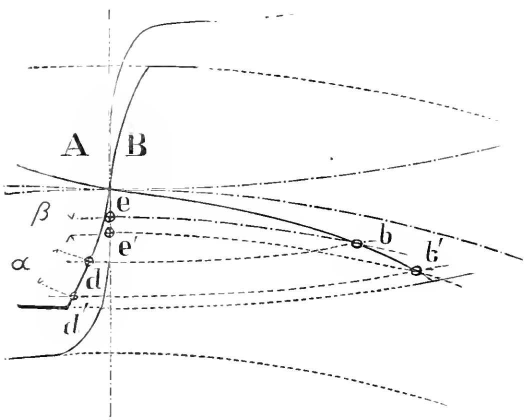

Fig. 10.

Considering a single gear wheel, the length of the outside branch of

the "path of contact" is limited by its egress from the circle circumscribing the extreme points of the teeth; the limit of the inside branch, however, remains undetermined until another wheel is brought into gear. The limited outside branch of that second wheel, in coinciding with the inside branch of the first one, determines the latter's limit for that particular couple. The inside branch is short when the mate is a small wheel, it is longer for larger wheels and racks, and assumes a still greater length when the mate becomes an inverted gear wheel. The number of teeth that are in gear at the same time depends on the length of the "path of contact."

Clearing Curves.

The lower limit or root of the useful portion of the flank is not constant for any particular gear wheel but depends on the size of the mate, and the space is extended below the root for the sole purpose of making room for the entering tooth of the mating gear. For any particular mate, the form below the root should be determined by the space needed for the motion of the entering tooth; however, since practice requires that there should be a clearance, it is proper to assume that the tooth of the mate be long enough to touch the bottom of the space, and after describing the space which this tooth requires, shorten the tooth again to the original height. In this way a strengthening fillet will be formed at the base of the tooth, which is the greater the smaller the gearing mate is. But if the wheel belongs to a set, and may be used with any size mate, it is advisable to make the fillet as small as the rack requires, and this is just what the above-described odontograph accomplishes.

Wear of Gear Wheels.

The investigation relating to the probable wear, and the liability of a consequent getting out of shape, can likewise be made with ease. While the point of contact travels from b to b' (Fig. 10), the portion $e\ e'$ of the tooth B will come in contact with the portion $d\ d'$ of the tooth A. At the beginning the points e and d are bearing, and finally the point e' will meet the point d'. The operation is partially a rolling and partially a slipping one. Denoting the lengths $d\ d'$ with α, and $e\ e'$ with β, the slip will amount to the difference $\alpha - \beta$. Assuming the pressure between the teeth to be uniform, the wear on each tooth is likely to be proportional to the slip. The wear on the tooth

A, however, will be distributed over the space $d\ d' = \alpha$, while that of the tooth *B* is confined to the less space $e\ e' = \beta$; hence the average depth of wear on the space $d\ d'$ is expressed by the ratio $\frac{\alpha - \beta}{\alpha}$ against that on the space $e\ e'$ at the ratio of $\frac{\alpha - \beta}{\beta}$. Thus, by dividing the "path of contact" in a number of integral portions, a diagram of the relative depth of wear can be constructed. In Fig. 11 such diagrams are represented in case of a rack gearing into a pinion of 27 teeth, both for cycloidal and involute teeth. A glance will show that cycloidal gears are far superior to involute teeth in this respect, as on the former the tendency is to wear exactly uniform, at least on either side of the pitch line, though the wear is not the same on both sides.

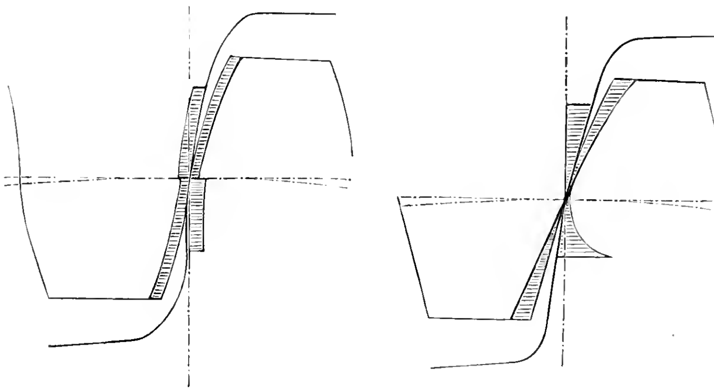

Fig. 11.

On involute teeth, there being no tendency to wear on the pitch line, a more rapid wearing out of shape will follow. The difference is attributable to the fact that the one form has a radial element at the pitch line while the other has not; for the slip being infinitely small at that point, the wear receives a definite depth only if the travel of the point of contact in relation to the curve of the tooth is infinitely slow at the same moment, giving this point, as it were, more *time* to wear, and this can only happen if the corresponding element of the tooth-form is radial. Moreover, in cycloidal wheels, the proportion of α and β is equal to the proportion of the paths of the centres of the rolling circles while describing those portions, which being constant on

each side of the centre line for any particular couple, will account for the uniform wear of cycloidal gears on each face.

Of course the diagrams, Fig. 11, must not be understood as representing the actual shape of the teeth after wear has taken place, for after the least perceptible wear the teeth will no longer be correct, and the condition will be changed so that the high points will wear more rapidly. Both diagrams, however, indicate a tendency of greater wear at the flank of the teeth.

Selection of Form.

If the form of the teeth of the original rack (or wheel) is adopted at random, it may happen that the teeth of pinions evolved from this rack become thinner below the pitch-circle than if the flanks were

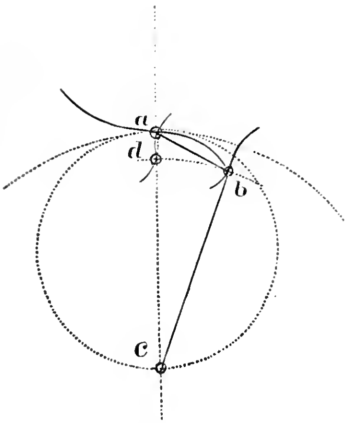

Fig. 12.

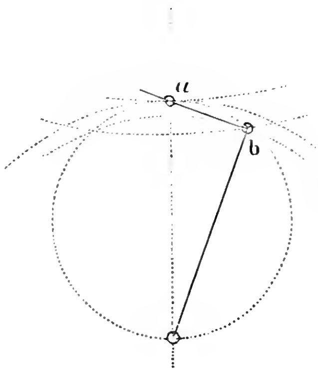

Fig. 13.

radial, or the point of the rack-tooth, in emerging from the gearing, may cut into the flank of the tooth. This can only happen if any element of the flank (*d*, Fig. 12) becomes more convergent towards the centre-line of the tooth than the radius vector of that element, or (revolving the element in question into the "path of contact," *b*) if the angle *a b c* is less than 90°. This danger increases as the diameter of the wheel is lessened or the centre, *c*, moved towards the point *a*; hence the reduction of the pinion is *limited* by the form adopted for the original tooth. For the cycloidal form, the smallest pinion admissible has a radius equal to the diameter of the rolling circle when the above-mentioned angle is equal to 90° for all points of the inner

branch of the "path of contact" and all elements of the flank are radial. For other than cycloidal forms, the "path of contact" must remain within this circle (Fig. 12) in order that the said angle for no portion of the "path" should be less than 90°. In the case of involute teeth, where the "path of contact" is represented by the line *a b* (Fig. 13), the used portion of the "path" must never extend beyond the point *b* (which, by the way, is the point of contact of the rolling line with the evolute circle), or, in other words, the point *b* must never be located within the outside line or circle of the mating rack or wheel.

In making the template of an odontograph, the question is pertinent: What is the condition that must be complied with to prevent an undercutting of a given smallest pinion?

That form is undoubtedly the limit in this respect which produces a radial flank in the smallest pinion, namely the cycloid, *A* (Fig. 3), but if another form is chosen (say *B*), care must be taken that the corresponding "path of contact," *a b'*, will remain within the rolling circle, *a b*, of the cycloid *A*. The requisite condition can be studied by comparing two elements, α and β, of the forms *A* and *B*, both having the same distance from the pitch line. It will be remembered that the elements α and β respectively form right angles with the right lines *a b* and *a b'*. When the point *b'* is within the rolling circle, the vertical inclination of β will accordingly be greater than that of α and *vice versa;* hence, in order to prevent a passing of the "path of contact" of the form *B* beyond the arc *a b*, *the vertical inclination of no element of that form should be less than that of the corresponding element of the cycloidal form A.*

Distinction Between Driving and Driven Gear.

Some mechanics, especially watchmakers, make it a practice to make the teeth of the driving wheel higher above the pitch line than those of the driven wheel. An unequal effect of friction, affecting the consequent loss of power, can be the only reason to which this practice may be assigned, and the problem may be reduced to this question: If the teeth of one pair of gear wheels are somewhat too long, will it be most advantageous to shorten the teeth of both wheels uniformly or not? Let Fig. 14 represent two such gear wheels, with their "path of contact" *b a b'*, the upper wheel, *A*, to be the driver. But for the friction on the face of the teeth, the transmission of force

would always be at right angles to the elements in contact and, consequently, would always pass through the point of pitch contact, a. Owing to friction, however, this line of force is deflected by the angle of friction. So, for instance, at the first point of contact, b, the line of force is $b\ c$ (the angle $a\ b\ c$ being that of friction between the teeth). The proportion of the momenta of forces is as the distances of the centres A and B from this line, or as $A\ c$ to $B\ c$ (owing to similar triangles), against the proportion $A\ a$ to $B\ a$, if there were no friction between the teeth. The distance $a\ c$ represents, as it were, the ratio of loss by friction while the teeth are in contact at b. For the last point of contact, b', the line of force is $b'\ c'$ (angle $a\ b'\ c'$ = angle $a\ b\ c$), the proportion of the momenta of forces $A\ c'$ to $B\ c'$, and the ratio of loss by friction is $a\ c'$, which is less than $a\ c$. The friction appears thus more unfavorable at b than it does at b', and a reduction of the "path of contact" should be effected on the former end. If this reduction is carried to a point b'', for which the angle $c'\ b''\ a$ equals the angle $c'\ b'\ a$ (the angle of friction), the effect of friction at that point b'' will be no more unfavorable than it is at b'. The corresponding reduction of the height of teeth of the driven wheel is furnished by the point b''.

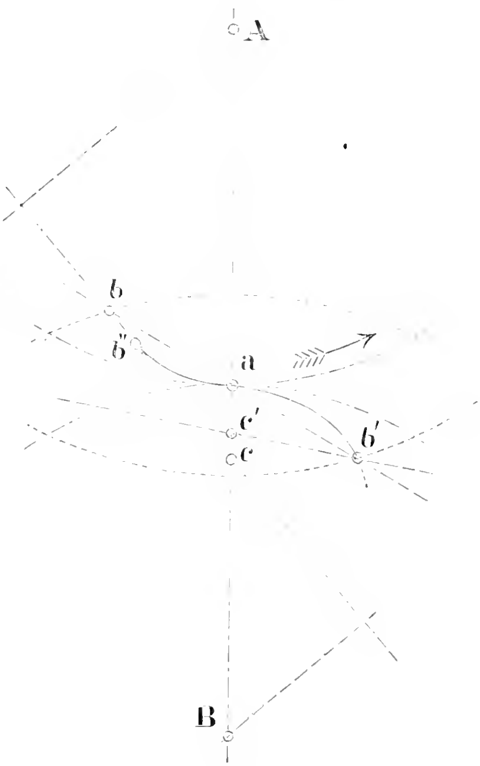

Fig. 14.

According to this, if in any special case the indicated correction is desired, the initial and terminal points, b and b', of the "path of con-

tact" should be mutually so located that *the lines b c and b′ c′ forming with the lines a b and a b′, on the side of the driven wheel, angles equal to the angle of friction of the teeth in contact, should both intersect the line of centres, A B, in the same point.*

DIMENSIONS AND PERFORMANCE OF THE HULL AND MACHINERY OF THE UNITED STATES STEAMER "DISPATCH," WITH ANALYSES OF THE POWER DEVELOPED.

By Chief Engineer Isherwood, U. S. Navy.

Accurate and complete data regarding vessels and their machinery, especially in the relation of the effect produced by the latter upon the former, are so valuable to the engineer, and so scarce, that the following facts in the case of the *Dispatch* a merchant yacht-built and brig-rigged screw steamer, purchased for the United States Navy, will be of service in several respects.

They show the propelling efficiency of her screw, and the development of power with it possible under the conditions of the vessel, and of the space displacement of her pistons per stroke with the mean net pressure upon them; also, the steam producing capacity of the boilers with common anthracite, and the cost of the power in fuel given by small simple engines using saturated steam above medium initial pressure and with more than the average measure of expansion.

The analyses of the power developed, rendered possible by the mean data from the very large number of indicator diagrams taken, show in what direction and to what extent it was expended, determine the resistance of the vessel at the experimental speeds, and ascertain its kind, and explain the cause of the inferior economic effect produced by the coal in proportion to power developed.

Hull.

The hull is of wood, coppered, and modeled for a yacht with much dead rise at the greatest transverse section. In addition to the proper central keel there is, on each side, a bilge keel, 50 feet long, the centre of which, transversely to the hull, is 9 feet 2 inches from the centre of the central keel. Each bilge keel is in cross section 25 inches wide

on top, tapering to $9\frac{1}{4}$ inches wide on bottom, and 20 inches deep. The following are the principal dimensions of the hull:

Length from forward edge of rabbet of stem to after side of body of sternpost, . . .	174 feet.
Extreme breadth, . . .	25·50 feet.
Depth at centre of length from top of deck plank to lower edge of rabbet of keel, . .	15·33 feet.
Depth at centre of length from water line to lower edge of rabbet of keel, . . .	10·25 feet.
Depth of keel at centre of length below the lower edge of its rabbet, . . .	0·75 foot.
Breadth of keel, . . .	1·00 foot.
Draught of water forward, . . .	11·17 feet.
Draught of water aft, . . .	12·83 feet.
Mean draught of water, . . .	12·00 feet.
Area of the greatest immersed transverse section to 12 feet draught, exclusive of projected cross area of bilge keels, ...	186·58 sq. ft.
Area of the water section at 12 feet draught, .	3163·34 sq. ft.
Displacement, exclusive of bilge keels, at 12 feet draught, ...	19328·64 cu. ft.
Displacement, exclusive of bilge keels, at 12 feet draught, ...	552·25 tons.
Centre of gravity of displacement abaft centre of length of water line, . . .	4·45 feet.
Centre of gravity of displacement below the water line, ...	7·345 feet.
Displacement per inch of draught at 12 feet draught,	7·5318 tons
External immersed, or wetted, surface of the hull, exclusive of bilge keels, from bottom of central keel to 12 feet draught of water, . .	5100·00 sq. ft.
Surface of the two bilge keels, . .	416·00 sq. ft.
Total immersed, or wetted, surface, . .	5516·00 sq. ft.
Ratio of length to breadth, . .	6·8235
Ratio of greatest immersed transverse section to its circumscribing parallelogram, . .	0·7138
Ratio of water section to its circumscribing parallelogram, ...	0·7129

Ratio of displacement to its circumscribing parallelopipedon, ...	0·4250
Ratio of displacement to a solid having for base the greatest immersed transverse section, and, for length, the length of the hull, . .	0·5954

Engines.

There are two vertical, direct acting, simple engines, connected at right angles upon the same crank shaft. Each cylinder has, in addition to its main slide valve with a Stephenson link reversing gear, an independent adjustable slide cut-off valve. There is no exhaust lead, and the steam cushioning commences when the pistons are at 0·1667 of the end of their stroke. There is one tubular surface condenser, with the exhaust steam on the outside of the tubes, and the refrigerating water within them. The tubes are in two groups, one above the other, and the refrigerating water passes first through the tubes of the lower group, returning through those of the upper group. There are two vertical, single acting air pumps, and two single acting feed pumps. An air pump and a feed pump are worked from a lever which receives its motion from the crosshead of each engine. The refrigerating water is driven through the condenser by a centrifugal pump. The case of the pump is 46 inches in diameter over all, and 7 inches in width. The fans are 6 inches deep radially, set on arms 18 inches long from the axis to the centre of the fan. The pump is operated by one independent steam cylinder of 12 inches diameter and 10 inches stroke of piston. The condenser, the pump and the independent cylinder are much too large in proportion to the weight of steam obtainable per hour from the boilers.

The cylinders and all the connecting steam pipes are well felted and lagged, but there are no steam jackets. The following are the principal dimensions of the engines:

Number of cylinders, . .	2.
Diameter of one cylinder, . .	$33\frac{1}{8}$ inches.
Diameter of the other cylinder, . .	$34\frac{1}{4}$ inches.
Diameter of the piston rods (one to each cylinder),	$3\frac{5}{8}$ inches.
Aggregate net area of the pistons (exclusive of rods), ...	1719·7804 sq. in.
Stroke of the pistons, . . .	2·75 feet.

Aggregate space displacement of the pistons per stroke, ...	32·84303 cu. ft.
Aggregate space in the clearances and steam passages of both cylinders at one end, . .	2·28917 cu. ft.
Per centum of the space displacement of the pistons per stroke, in the clearances and steam passages, ...	6·97
Number of tubes (brass) in condenser, .	1294.
Outside diameter of condenser tubes, . .	$\frac{3}{4}$ inch.
Length of condenser tubes, . .	55 inches.
Aggregate condensing surface, measured on outside of tubes, ...	1164·5 sq. ft.
Number of air pumps (single acting), .	2.
Diameter of air pumps, . . .	18 inches.
Stroke of air pump pistons, . .	16 inches.
Aggregate space displacement of air pump pistons per stroke, ...	4·7123 cu. ft.
Number of feed pumps (single acting), .	2.
Diameter of feed pumps, . . .	$3\frac{5}{16}$ inches.
Stroke of feed pump plungers, . .	16 inches.
Aggregate space displacement of feed pump plungers per stroke, ...	0·1596 cu. ft.

Boilers.

There are two cylindrical steel boilers, placed opposite each other, with an athwartship fire room between them. The boilers discharge their gases of combustion into one chimney, whose axis is directly above the centre of the fire room. The steam from both boilers is delivered into an independent annular steam drum, surrounding the lower portion of the chimney, and by an arrangement of three stop valves this drum can be shut off at will, and the steam carried directly from the steam room of the boilers to the engines. No occasion, however, has ever arisen for thus excluding the steam from the drum. The boilers and drum were well felted and lagged.

The boiler shells were 11 feet in diameter, and 8 feet 8 inches in length, exclusive of the front connection projecting over the fire room. The back lower angle was beveled to a height of 2 feet $7\frac{1}{2}$ inches in a horizontal distance of $18\frac{3}{4}$ inches. The cylindrical portion of the shell was $\frac{11}{16}$ of an inch thick, and its seams were planed, butt-jointed

and covered with double longitudinal straps $\frac{9}{16}$ inch thick. The flat heads of the shells were $\frac{1}{2}$ inch thick; their seams were planed, butt-jointed and covered with single straps $\frac{5}{8}$ inch thick. All seams were double riveted and caulked. The gussets and stay plates were riveted to cylindrical shell and flat heads by angle iron $2\frac{1}{2}$ by $2\frac{1}{2}$ inches. The lower part of the front heads was $\frac{3}{4}$ inch thick; the back tube plate was $\frac{9}{16}$ of an inch thick; the gusset plates were $\frac{1}{2}$ inch thick; the stay plates were $\frac{3}{4}$ of an inch thick, and the stay rods in the steam room were $1\frac{1}{2}$ inches in diameter, spaced 12 inches between centres. The rivets for the cylindrical shell were $\frac{7}{8}$ inch in diameter, with 3 inches pitch; those for the flat heads were $\frac{7}{8}$ inch in diameter, with $2\frac{7}{8}$ inches pitch, and those for the connections were $\frac{3}{4}$ inch in diameter, with $1\frac{7}{8}$ inches pitch.

Each boiler contained three cylindrical furnaces of 32 inches interior diameter and 6 feet $5\frac{3}{8}$ inches extreme length. The grate surface in each furnace averaged 2·6144 feet wide and 6 feet $4\frac{1}{2}$ inches long, making $16\frac{2}{3}$ square feet. Each furnace was in three sections, separated by stiffening rings $\frac{1}{2}$ inch thick and $37\frac{3}{4}$ inches outside diameter. Each section was composed of a single plate $\frac{7}{16}$ inch thick, with a planed seam, butted and secured by an inside welt. Each furnace had a cast iron front, with an opening of 12 by 18 inches for the door. The horizontal distance between the centres of the furnaces, transversely, was $34\frac{9}{16}$ inches. The least water space between the furnaces and boiler shell was $2\frac{5}{8}$ inches, and between the furnaces $5\frac{3}{4}$ inches. Manholes were made in all the spandrels above and below the furnaces.

Each boiler has a single back connection built in it, which connection is divided into three compartments by iron plates bolted in, so that each furnace has an independent back connection. The width of the connection, lengthwise the boiler, is $20\frac{3}{8}$ inches in the clear; its top is a quadrantal arc of 16 inches radius, and a flat horizontal space of $4\frac{3}{8}$ inches; its back is flat, and separated from the back of the boiler by a flat water space 6 inches wide, including thicknesses of metal. The sides of the back connection are concentric with the cylindrical shell of the boiler, and separated from it by a water space 6 inches wide, including thicknesses of metal. The flat water spaces have socket bolts at intervals of 7 inches between centres. The bottom of the connection contains the brick bridge walls, 6 inches high above the top of the grate bars, extending clear across the connection and supported on a cast iron base.

The tubes are horizontal fire tubes, returned from the back connection above the furnaces to the uptake, and they are arranged in two groups of ninety-five each. Each tube is of brass, seamless, 3 inches in outside diameter, 2·8 inches in inside diameter and 6 feet $4\frac{11}{16}$ inches long in the clear of the tube plates. The tubes are in eight rows vertically and twenty-four rows horizontally, the two outer tubes of the upper row being omitted. The distance between the centres of the tubes vertically is 4 inches, and horizontally $4\frac{3}{8}$ inches. The total height occupied by the tubes, from the bottom of the tubes of the lower row to the top of the tubes of the upper row, is 35 inches. The vertical water space between the two groups of tubes is 12 inches wide in the clear.

The uptake is of sheet iron, lined with brick and bolted to the front of the boiler above the level of the furnaces.

The following are the principal dimensions of the boilers:

Number of boilers,	2.
Diameter of boiler,	11 feet.
Length of boiler, exclusive of uptake,	8 feet 8 inches.
Number of furnaces in each boiler,	3.
Interior diameter of furnaces,	2 feet 8 inches.
Length of grate surface,	6 feet $4\frac{1}{2}$ inches.
Mean breadth of grate surface,	2·6144 feet.
Aggregate area of grate in both boilers,	100 square feet.
Number of tubes in each boiler,	190.
Outside diameter of tubes,	3 inches.
Inside diameter of tubes,	2·8 inches.
Length of tubes between the tube plates,	6·390625 feet.
Diameter of the chimney,	4 feet 6 inches.
Height of the chimney above the level of the grates,	43 feet 6 inches.
Aggregate cross area over bridge walls for draught in both boilers,	16·5000 sq. ft.
Aggregate cross area through tubes for draught in both boilers,	16·2490 sq. ft.
Cross area of chimney,	15·9042 sq. ft.
Aggregate area of heating surface in the furnaces of both boilers,	174·1018 sq. ft.
Aggregate area of heating surface in the back connections of both boilers,	212·1726 sq. ft.

Aggregate area of heating surface in the tubes of both boilers, calculated for inside diameter,	1780·1256 sq. ft.
Aggregate area of heating surface in the uptakes of both boilers, . . .	47·6000 sq. ft.
Total area of heating surface in both boilers,	2214·0000 sq. ft.
Ratio of the grate surface to the cross area above the bridge walls, . . .	6·0606
Ratio of the grate surface to the cross area through the tubes, . . .	6·1542
Ratio of the grate surface to the cross area of the chimney, . . .	6·2876
Ratio of the heating surface to the grate surface,	22·1400
Exterior diameter of the steam drum, .	6 feet 6 inches.
Interior diameter of the steam drum, .	4 feet 6 inches.
Height of the steam drum, . .	6 feet 3 inches.
Steam superheating surface in the steam drum, .	88·3575 sq. ft.
Greatest height of steam room in boilers, . .	3 feet.
Aggregate steam room in shells of both boilers,	360 cubic feet.
Steam room in the steam drum alone, .	108 cubic feet.
Total steam room, . . .	468 cubic feet.

Screw.

There is one true screw, with the blades curved backwards on a radius of 37 feet for the forward edge. The screw is bronze, and of uniform length from hub to periphery.

Diameter of the screw, . . .	11·10 feet.
Diameter of the hub, . . .	1·75 feet.
Pitch (by measurement after screw was cast), .	19·90 feet.
Length of the screw in the direction of its axis,	1·4583 feet.
Number of blades, . . .	4.
Fraction used of the pitch, . .	0·2931
Projected area of the blades on a plane at right angles to axis, ...	27·6611 sq. ft.
Helicoidal area of the blades, . .	37·8914 sq. ft.
Weight of the screw, . . .	4520 pounds.
Thickness of the blades of fillet of hub, .	4·4375 inches.
Thickness of the blades at periphery, . .	0·375 inch.

Trial of the "Dispatch" made in Chesapeake Bay by a Board of U. S. Naval Engineers to ascertain her Maximum Speed, Power and Consumption of Coal.

The following trial was made in Chesapeake Bay, by a Board of United States Naval Engineers, with the *Dispatch* at her deep load draught of water, to ascertain the maximum speed which could be permanently maintained in smooth water and uninfluenced by wind or current, burning anthracite in the condition in which it was delivered by the contractors, and with only the regular firemen of the engineer department of the vessel; also, to ascertain the power required for this speed, and the consumption of coal to produce it.

The trial continued nine consecutive hours, during which the vessel was run four and a half hours in a straight line in one direction, and then four and half hours in the opposite direction, in order to neutralize the effects of wind and current. The water was smooth. The speed was noted by a taffrail log, by a patent log, and by the shore marks according to the Coast Survey chart. The wind was a gentle breeze, alternately on the port bow and starboard quarter.

Indicator diagrams were taken from each end of each cylinder every fifteen minutes, at which times there were noted in the appropriate columns of a tabular record, or log, the steam pressure in the boiler, the vacuum in the condenser, the height of the barometer, the number on the counter, and the temperatures of the air on deck and in the engine room, of the injection water, of the discharge water, and of the feed water in the hot well.

The throttle valve was kept wide open throughout, and the full throw of the Stephenson links were used.

The trial was begun with fresh, clean fires, of noted thickness, and ended with them in the same condition as nearly as could be judged. All the anthracite consumed and its refuse were weighed. The pressure of the steam and the height of the water in the boilers were left at the close of the trial the same as at its commencement.

The following are the mean results from all the observed data:

Date of the experiment,		January 14, 1880.

Vessel.

Vessel's draught of water, in feet and inches:	forward,	11·6
	mean,	12·2
	aft,	12·10
Vessel's greatest immersed transverse section in square feet, including projection of bilge keels,		195·552

Vessel's displacement, in tons, including bilge keels, .	574·06
Vessel's external immersed or wetted surface, in square feet, including surface of bilge keels, . .	5576·00

Engines.

Steam pressure in boilers, in pounds per square inch above the atmosphere, ...	52.
Position of the throttle valve, . . .	Wide open.
Fraction of the stroke of the pistons completed when the steam was cut off, ...	0·1166
Number of times the steam was expanded, . .	5·7418
Fraction of the back stroke of the piston completed when the steam was cushioned, ...	0·8333
Vacuum in the condenser, in inches of mercury, .	25·50
Pressure in the condenser, in pounds per square inch above zero, ...	2·076
Height of the barometer, ...	29·73
Number of revolutions made per minute by the circulating pump, ...	150.
Number of double strokes made per minute by the pistons, ...	64·5333

Temperatures.

Temperature, in degrees Fahrenheit, of the air on deck,	44·0
Temperature, in degrees Fahrenheit, of the injection water, ...	34·5
Temperature, in degrees Fahrenheit, of the discharge water, ...	73·0
Temperature, in degrees Fahrenheit, of the feed water,	100·0
Temperature, in degrees Fahrenheit, of the air in the engine room, . . , . .	82·0

Speed.

Speed of the vessel per hour, in geographical miles of 6086 feet, ...	10·75
Slip of the screw, in per centum of its speed, .	15·0914

Rate of Combustion.

Pounds of anthracite consumed per hour, . .	1550·
Pounds of refuse per hour from the anthracite, in ash, clinker, etc., ...	310·
Pounds of combustible or gasifiable portion of the anthracite consumed per hour, ...	1240·
Per centum of the anthracite in refuse of ash, clinker, etc.,	20·
Pounds of anthracite consumed per hour per square foot of grate surface, ...	15·50
Pounds of anthracite consumed per hour per square foot of heating surface, ...	0·7001

Pounds of combustible consumed per hour per square foot of grate surface, ...	12·40
Pounds of combustible consumed per hour per square foot of heating surface, ...	0·5601

Steam Pressures in Cylinders, Per Indicator.

Pressure on pistons in pounds per square inch above zero, at commencement of their stroke, . . .	55·90
Pressure on pistons in pounds per square inch above zero, at point of cutting off the steam, . . .	53·85
Pressure on pistons in pounds per square inch above zero, at end of their stroke, ...	14·23
Mean back pressure against pistons, including cushioning, in pounds per square inch above zero, . .	6·63
Mean back pressure against pistons for the portion of their stroke during which the steam was not cushioned, in pounds per square inch above zero, . . .	5·90
Back pressure against pistons, in pounds per square inch above zero, at the point where the cushioning of the steam began, ...	5·39
Indicated pressure on the pistons, in pounds per square inch, ...	21·776
Net pressure on the pistons, in pounds per square inch, .	20·026
Total pressure (exclusive of cushioning) on the pistons, in pounds per square inch, reduced in the ratio of the stroke of the piston to the fraction of the stroke completed when the cushioning began, ...	26·693

Horses-Power.

Indicated horses-power developed by the engines, .	402·7950
Net horses-power developed by the engines, . .	370·4249
Total horses-power developed by the engines, . .	493·7458
Total horses-power developed from the expanded steam alone, ...	406·8089

Economic Results.

Pounds of anthracite consumed per hour per indicated horse-power, ...	3·8481
Pounds of anthracite consumed per hour per net horse-power, ...	4·1844
Pounds of anthracite consumed per hour per total horse-power, ...	3·1393
Pounds of combustible consumed per hour per indicated horse-power, ...	3·0785
Pounds of combustible consumed per hour per net horse-power, ...	3·3475
Pounds of combustible consumed per hour per total horse-power, ...	2·5114

WEIGHT OF STEAM ACCOUNTED FOR BY THE INDICATOR.

Pounds of steam present per hour in the cylinders at the point of cutting off, calculated from the pressure there,	5355·6091
Pounds of steam present per hour in the cylinders at the end of the stroke of the pistons, calculated from the pressure there, ...	9149·5487
Pounds of steam condensed per hour in the cylinders to furnish the heat transmuted into the total horses-power developed from the expanded steam alone, . .	1078·8964
Sum of the two immediately preceding quantities, .	10228·4451

DISTRIBUTION OF THE POWER DURING THE ABOVE PERFORMANCE.

The following distribution of the average indicated power developed by the engines during the above performance, is made on the supposition: 1st. That the power required to work the engines *per se*, or unloaded, is what was due to a pressure of $1\frac{3}{4}$ pounds per square inch of the piston. 2d. The subtraction of the power, thus calculated, from the indicated power, leaves the net power, of which $7\frac{1}{2}$ per centum is taken for the power absorbed by the friction of the load. 3d. The power expended in overcoming the resistance of the water to the surface of the screw blades is calculated on the data that each square foot of this surface moving in its helical path, with a velocity of 10 feet per second, experiences a resistance of 0·45 pound, which resistance for other speeds varies as the square of the speed. 4th. Deducting the sum of the powers absorbed by the friction of the load and expended in overcoming the resistance of the water to the surface of the screw blades, from the net power, leaves a remainder which is expended in the slip of the screw and in the propulsion of the hull. Dividing this remainder in the proportion of the speed of the slip and the speed of the vessel, there is obtained for each the power expended on it.

	Horses-Power.		Per Centum of the Net Horses-Power.
Indicated power developed by the engines,	402·7950		
Power expended in working the engines, *per se*,	32·3701		
Net power applied to the crankpins, .	370·4249	or	100·0000
Power absorbed by the friction of the load,	27·7819	or	7·5000
Power expended in overcoming the resistance of the water to the surface of the screw blades,	25·6238	"	6·9174
Power expended in the slip of the screw, .	47·8426	"	12·9156
Power expended in the propulsion of the vessel,	269·1766	"	72·6670
Totals, ...	370·4249	"	100·0000

Thrust of the Screw during the above Performance.

The thrust of the screw, as it would have been measured by a dynamometer, during the above performance, calculated from the data therein given and in the distribution of the power, is as follows:

The horses-power expended in the propulsion of the vessel according to the distribution of the power, being 269·1766, is equal to $(269{\cdot}1766 \times 33000 =)$ 8882827·8 foot-pounds of work per minute; and the speed of the vessel being 10·75 geographical miles per hour, is equal to $\left(\frac{10{\cdot}75 \times 6086}{60} = \right)$ 1090·4083 feet per minute; hence, the resistance of the vessel at that speed, or its equivalent the thrust of the screw, is $\left(\frac{8882827{\cdot}8}{1090{\cdot}4083} = \right)$ 8146·3315 pounds.

Determination of the Power Expended in Overcoming the Resistance of the Water to the Immersed External or Wetted Surface of the Hull.

Taking the resistance of the water to one square foot of rolled copper surface, moving in it with the velocity of 10 feet per second, to be 0·45 pound; and at other velocities to be this quantity modified in the ratio of their squares to the square of 10: and deducing from the speed of the vessel the mean speed of its immersed surface due to the inclination of its horizontal water lines to its longitudinal central plane, there results for that speed 18 feet per second; and, consequently, a surface resistance of $(10^2 : 0{\cdot}45 : : 18^2 :)$ 1·458 pounds per square foot moving with that velocity.

As the immersed external or wetted surface of the vessel during the above performance was 5576 square feet, the power expended in overcoming its resistance was $\left(\frac{5576 \times 1{\cdot}458 \times 18 \times 60}{33000} = \right)$ 266·0664 horses, which are substantially the same as the 269·1766 horses-power expended in the propulsion of the vessel, according to the preceding "distribution of the power" developed by the engines. In other words, the entire resistance of the vessel was sensibly that of the water to its immersed external surface; and, consequently, no engine power was expended in overcoming the resistance of the water to displacement by the progress of the vessel. That is to say, the difference between the power exerted by the fore body of the vessel in raising

the displaced water from the centre of gravity of the greatest immersed transverse section of the vessel to the general water level, and the power exerted upon the after body of the vessel in the direction of its motion by the ascending column of water caused by the forward movement of the vessel, were sensibly equal.

In the *Dispatch*, therefore, as in many other excessively sharp vessels, with long after bodies relatively to combined draught of water and speed, nearly or quite the whole of the engine power applied to the propulsion of the vessel is expended in overcoming the resistance of the water to its immersed external surface; the power exerted by its fore body in displacing water being nearly or wholly recovered by the power exerted propulsively on its after body by the column of water rising vertically to fill the void left by the passage of the vessel.

Average Performance under the Conditions of Ordinary Practice, in Smooth Water Uninfluenced by Wind or Current.

The following is the average performance of the *Dispatch*, in the Potomac River and Chesapeake Bay, under the conditions of ordinary practice, and embracing the whole of her steaming from November 8, 1880 to March 30, 1881, the water being smooth and the breeze gentle abeam. During this steaming there were in the bunkers, on an average, 90 tons of coal, the full quantity being 130 tons. The aggregate time of steaming was 358 hours; the fuel was anthracite consumed by natural draught. The vessel's draught of water during this time averaged 11 feet 2 inches forward and 12 feet 10 inches aft. A regular tabular log was kept, indicator diagrams were taken at intervals, and all the quantities were accurately ascertained.

Hull.

Vessel's mean draught of water in feet, . . .	12·
Vessel's greatest immersed transverse section, in square feet, including projection of bilge keels, . . .	191·3
Vessel's displacement, in tons, including bilge keels, .	559·
Vessel's external immersed or wetted surface, in square feet, including surface of bilge keels, . . .	5516·

Engines.

Steam pressure in boilers, in pounds per square inch above the atmosphere, ...	49·3
Position of the throttle valve, . . .	$\frac{5}{8}$ open.

Fraction of the stroke of the pistons completed when the steam was cut off,	0·112
Number of times the steam was expanded,	5·8872
Vacuum in the condenser, in inches of mercury,	25·50
Pressure in the condenser, in pounds per square inch above zero,	2·45
Barometer, in inches of mercury,	30·
Number of revolutions made per minute by the circulating pump,	125·
Number of double strokes made per minute by the pistons,	59·484

RATE OF COMBUSTION.

Pounds of anthracite consumed per hour,	1253·50
Pounds of refuse per hour from the anthracite, in ash, clinker, etc.,	269·50
Pounds of combustible or gasifiable portion of the anthracite consumed per hour,	984·00
Per centum of the anthracite in refuse of ash, clinker, etc.,	21·50
Pounds of anthracite consumed per hour per square foot of grate surface,	12·535
Pounds of anthracite consumed per hour per square foot of heating surface,	0·5662
Pounds of combustible consumed per hour per square foot of grate surface,	9·840
Pounds of combustible consumed per hour per square foot of heating surface,	0.4444

TEMPERATURES.

Temperatures, in degrees Fahrenheit, of the air on deck,	62·5
Temperature, in degrees Fahrenheit, of the air in the engine room,	91·0
Temperature, in degrees Fahrenheit, of the injection or refrigerating water,	63·5
Temperature, in degrees Fahrenheit, of the discharge water,	85·0
Temperature, in degrees Fahrenheit, of the feed water.	107·9

SPEED.

Speed of the vessel per hour, in geographical miles of 6086 feet,	9·9195
Slip of the screw, in per centum of its speed,	15·00

STEAM PRESSURES IN CYLINDERS, PER INDICATOR.

Pressure on pistons, in pounds per square inch above zero, at commencement of their stroke,	48·60
Pressure on pistons, in pounds per square inch above zero, at point of cutting off the steam,	46·80
Pressure on pistons, in pounds per square inch above zero, at end of their stroke,	11·15
Mean back pressure against pistons, including cushioning, in pounds per square inch above zero,	5·90

Mean back pressure against pistons, for the portion of their stroke during which the steam was not cushioned, in pounds per square inch above zero,	5·28
Back pressure against pistons, in pounds per square inch above zero, at the point where the cushioning of the steam began,	5·00
Indicated pressure on the pistons, in pounds per square inch,	18·434
Net pressure on the pistons, in pounds per square inch,	16·684
Total pressure (exclusive of cushioning) on the pistons, in pounds per square inch, reduced in the ratio of the stroke of the piston to the fraction of the stroke completed when the cushioning began,	22·834

Horses-Power.

Indicated horses-power developed by the engines,	314·2979
Net horses-power developed by the engines,	284·4605
Total horses-power developed by the engines,	389·3174
Total horses-power developed from the expanded steam alone,	323·2320

Economic Results.

Pounds of anthracite consumed per hour per indicated horse-power,	3·9882
Pounds of anthracite consumed per hour per net horse-power,	4·4066
Pounds of anthracite consumed per hour per total horse-power,	3·2197
Pounds of combustible consumed per hour per indicated horse-power,	3·1308
Pounds of combustible consumed per hour per net horse-power,	3·4592
Pounds of combustible consumed per hour per total horse-power,	2·5275

Weight of Steam Accounted for by Indicator.

Pounds of steam present per hour in the cylinders at the point of cutting off, calculated from the pressure there,	4154·6287
Pounds of steam present per hour in the cylinders at the end of the stroke of the pistons, calculated from the pressure there,	6559·1121
Pounds of steam condensed per hour in the cylinders to furnish the heat transmuted into the total horses-power developed by the expanded steam alone,	851·9174
Sum of the two immediately preceding quantities,	7411·0295

Distribution of the Power During the above Average Performance.

The following is the distribution of the power developed by the engines, calculated as precedingly described, during the above average

performance of the *Dispatch*, under the conditions of ordinary practice, in smooth water and uninfluenced by wind or current.

	Horses-Power.		Per Centum. of Net Horses-Power.
Indicated power developed by the engines, .	314·2979		
Power expended in working the engines, *per se*.	29·8374		
Net power applied to the crankpins, .	284·4605	or	100·0000
Power absorbed by the friction of the load, .	21·3345	"	7·5000
Power expended in overcoming the resistance of the water to the screw blades, .	20·0675	"	7·0546
Power expended in the slip of the screw,	36·4588	"	12·8168
Power expended in the propulsion of the vessel, ...	206·5997	"	72·6286
Totals, . . .	284·4605	"	100·0000

Thrust of the Screw During the Above Average Performance.

The thrust of the screw, as it would have been measured by a dynamometer, during the above average performance, calculated from the data just given, as precedingly described, is as follows:

The horses-power expended in the propulsion of the vessel, according to the above "distribution of the power," being 206·5997, is equal to ($206·5997 \times 33000 =$) 6817790·1 foot-pounds of work per minute; and the speed of the vessel being 9·9195 geographical miles per hour, is equal to $\left(\frac{9·9195 \times 6086}{60} = \right)$ 1006·16795 feet per minute; hence the resistance of the vessel at that speed, or its equivalent the thrust of the screw, is $\left(\frac{6817790·1}{1006·16795} = \right)$ 6775·996 pounds.

Determination of the Power Expended During the Above Average Performance, in Overcoming the Resistance of the Water to the Immersed External or Wetted Surface of the Hull.

Taking the resistance of water to one square foot of rolled copper surface, moving in it with the velocity of 10 feet per second, to be

0·45 pound; and at other velocities to be this quantity modified in the ratio of their square to the square of 10; and deducing from the speed of the vessel the mean speed of its immersed surface due to the inclination of its horizontal water lines to its longitudinal central plane, there results for that speed 16·58 feet per second, and, consequently, a surface resistance of $(10^2 : 0{\cdot}45 :: 16{\cdot}58^2 =)$ 1·237 pounds per square foot moving with that velocity.

As the immersed external or wetted surface of the vessel, during the above average performance, was 5516 square feet, the power expended in overcoming its resistance was $\left(\frac{5516 \times 1{\cdot}237 \times \overline{16{\cdot}58 \times 60}}{33000} = \right)$ 205·6912 horses. Now, according to the "distribution of the power" developed by the engines during the average performance, the power expended in the propulsion of the hull was 206·5997 horses; consequently, the entire resistance of the vessel was sensibly that of the water to its immersed external surface. This result, from data wholly independent of that given by the Board of Naval Engineers for the previous experiment, and obtained by different persons and at different times, shows both the accuracy of the observations and of the constants, as well as the correctness of the method and the deduction.

The Economic Result.

The cost of the power developed by the engines in fuel appears very great, reaching to nearly four pounds of anthracite consumed per hour per indicated horse-power, the refuse from the coal being a little over one-fifth of the latter: and the cause will be found, as might be expected, in the enormous cylinder refrigeration due to the work of expansion by steam of high initial pressure largely expanding, the point of cutting off being a little beyond one-ninth of the stroke of the pistons from the commencement. Under these circumstances, when saturated steam is used with simple engines having cylinders of very moderate dimensions, without steam jackets, as in the *Dispatch*, the cylinder condensation is excessive and entirely defeats the economy which might be obtained from the same measure of expansion employed with superheated steam in steam-jacketed cylinders of large dimensions. In fact, saturated steam cut off at one-ninth of the stroke of the piston, in cylinders like those of the *Dispatch*, produces no greater economy than if it was used with very much less expansion.

Assuming the economic vaporization of the boilers to have been

about eight pounds of water, from the temperature of the feed, per pound of anthracite consumed, which was probably near the truth, the results from the indicator diagrams show that during about the first ninth of the stroke of the pistons, about 57½ per centum of all the steam entering the cylinders was condensed by their surfaces; including, of course, the surfaces in the steam passages up to the valves. Of course, during this one-ninth of the stroke of the pistons no power whatever was obtained from 57½ per centum of all the steam generated in the boilers. From the point of cutting off the steam to the end of the stroke of the pistons there went on a continuous re-evaporation of this water of condensation under the continuously decreasing pressure due to the continuous development of space by the moving pistons, but the steam produced by this re-evaporation pressed the pistons for only the remainder of their stroke from the point where the re-evaporation took place. The re-evaporated steam did not, probably, act through more than 45 per centum of the stroke of the pistons, and during that with a very small average measure of expansion, the expansion becoming less and less as the re-evaporation took place later and later. The intended measure of expansion due to the cutting off at one-ninth of the stroke of the pistons from the commencement thus applies to only (100·0—57·5=) 42½ per centum of the steam generated in the boilers. When the pistons reached the end of their stroke the steam supplied by the re-evaporation was sufficient to leave only 22 per centum of the quantity generated in the boilers condensed; so that a large portion of the expansion part of the indicator diagram was due to this re-evaporation. The 22 per centum of the steam generated in the boilers, which was present in the cylinders as water of condensation when the pistons arrived at the end of their stroke, were re-evaporated to the condenser under its much less pressure during their return or exhaust stroke, producing no effect upon them.

The heat for the re-evaporation in the cylinders of the water of condensation was supplied by the metal of the cylinders and by the contained heat of the water itself. The metal is first heated during the admission portion of the stroke of the piston by the entering steam which undergoes a corresponding condensation to supply the heat required; and then cooled during the expansion portion of the stroke by the continuous re-evaporation of the resulting water of condensation under the continuously decreasing pressure due to the expansion.

MECHANICAL DRAWING.

By Coleman Sellers, Jr.

A lecture delivered before the Franklin Institute, November 11th, 1881.

When Mr. John S. Clark lectured before you last summer, he told you that drawing is of three kinds: Representative, which treats of objects as they appear; Constructive, which shows how they are to be made, and Decorative, which treats of ornamenting them.

Of course it is beyond the possibilities of a single lecture to go very deeply into the consideration of any one of these co-ordinate themes, and all I hope to do this evening is to direct your attention to a few of the questions involved in the practice of the second of these arts, namely, *Constructive* Drawing. Constructive Drawing is generally of the kind we call *mechanical*, in contradistinction to *free-hand*. That is to say, in the one case we use instruments of precision to determine form and size, while in the other we depend entirely upon accuracy of eye and skill of hand for the proportion of the parts of the drawing. But this distinction is not absolutely rigid—all constructive drawings are not mechanical drawings, nor are all mechanical drawings constructive.

Drawing has been called the universal language—intelligible to all grades of civilization, irrespective of tongue or nationality. The engraved monuments of extinct races tell us their stories of bygone times and manners, and we read them more or less correctly, although we may know not a word of Assyrian, Aztec or Egyptian. The written language of the savage, as far as he has one, is a series of rude pictures and, indeed, we seldom meet minds so uneducated that they fail to recognize a picture of any familiar object.

We are told of the men of ready pencil who travel in foreign lands and make known their wants by a happy knack of off-hand sketching. There was the young man, for instance, who vainly tried to convey the idea of fried eggs to the obtuse peasant and who, having exhausted alike his vocabulary and his patience without the desired result, in sheer desperation seized paper and pencil and, by a rude sketch of a frying-pan and one of an egg, got the breakfast he wanted. Although I dare say, if the truth were known, to prevent the eggs being taken

for potatoes, he was obliged to supplement his drawing of the eggs with a portrait of the hen.

The universality of drawing, however, applies only to its representative phase. *Constructive* drawing has not the same quality—it is not universal in the sense that it conveys adequate ideas to all minds without regard to education. Representative drawing shows things as they appear, and hence appeals to all who can see. Constructive drawing proceeds upon certain known principles or *conventions*, and some knowledge of these we must have to understand drawings of this kind. Special knowledge is demanded alike of the man who makes and the man who uses the *working-drawing*, on the part of the draughtsman and on that of the artisan. The one must understand drawing, the other must understand drawings.

We do not possess an intuitive knowledge of constructive drawing; on the contrary, to many minds the simplest working drawing is merely an unintelligible maze of unrelated lines. Among artisans, the very men for whom drawings are made, we frequently find those, perhaps good workmen, who cannot receive their instructions in that form; and even among men who profess to have mechanical ideas, would-be inventors perhaps, we now and then meet those who have a perfect incapacity to explain to others with the pencil those ideas which they believe are yearning for expression. Ignorance of this kind, appearing as it so often does among men who must constantly have to do with working drawings, shows a lamentable deficiency in school and shop education.

Drawing of some kind is absolutely necessary to the useful arts: if we leave out of consideration those shapes or details which may be described in a few words, drawing becomes the only means of communication between the designer and the workman—the only method of conveying ideas of anything to be made. The simplest utensils, the most complicated machines, must be expressed graphically before they can be constructed. For the simpler forms, this drawing may be, it is true, only a sketch made by the foreman on the shop door; but it gives ideas of size and general shape which could not be expressed in words. The day has passed for these rough approximate sketches, however, and for many other equally crude makeshifts that were once common in shops. The needs of modern work demand drawings that will tell a straight story, that will express their meaning clearly and without equivocation, that are the result of a careful and system-

atic consideration of the subject shown, in all its bearings, and, furthermore, that will be a complete and accurate record of the machine when finished—a record which will enable any part to be reproduced as nearly as mechanical methods will permit.

Representative drawing considers *apparent* form and size—that is, the distance of the object drawn from the spectator is involved; and the relative size and positions of the parts, as shown in the drawing, are determined by the laws of Linear Perspective.

A perspective view—that is, a representative drawing—of a house or a locomotive as either appears, will give the best idea of the one or the other to the untechnical mind, especially if the actual colors of the natural objects be reproduced; but drawings of this kind would be of little use to the man who wishes to build a locomotive or a house. The constructive or working drawing does not consider alone the external semblance, but must dissect, as it were, the anatomy of the thing represented and show each part in its relation to every other; it must show the floors, the stairways, the doors and windows, and a multitude of other particulars in the case of the house or the various component parts of the locomotive, and it will in either case be more or less complete as it gives with greater or less minuteness these various details.

While representative drawing treats of color, of *apparent* form and *relative* size, constructive or, as it is usually termed in common parlance, mechanical drawing deals with *actual* form and *real* size.

Drawings may be as large as the objects drawn, in which case we say they are "full size," or, for convenience, they may be smaller or larger, "one-half" or "quarter size," or "double size," or any other multiple; but, in any case, all parts of the object are reduced or enlarged in the same ratio, or, as we say, to the same scale. The principles of constructive drawing are variously applied to suit different subjects, or the need of different craftsmen—architects, machinists, ship-builders, etc.; and by "mechanical drawing" to-night we will designate constructive drawing as applied to the needs of the machine shop.

Mechanical drawing represents objects as projected or thrown upon a plane surface: no account is made of distance or perspective; but the drawing appears as though its lines had been traced from the object on a transparent paper held against it. In fact it goes further, and indicates, in various ways, parts that are really invisible, and, by dotted lines and imaginary cross-sections, it displays details which perhaps

could not be seen from any standpoint from which the object could be viewed. Mechanical drawing is thus conventional from the outstart; that is, it is founded upon an understanding that certain things are to be expressed graphically in certain ways. Of these "conventions" the most important is that of projections. Descriptive Geometry, which is the science whose practical application is supposed to be in making mechanical drawings, and whose object is to "represent accurately upon plane surfaces all geometrical magnitudes as they exist in space",—Descriptive Geometry teaches us that objects are to be considered as projected upon three planes—a horizontal, a vertical, and others perpendicular to these, called side-planes.

Now, objects to be represented may be situated in either of the four *diedral* angles formed by the horizontal and vertical planes of projection; but for purposes of convenience we are told to consider all objects as being in the first angle, that is, above the horizontal in front of the vertical plane. I have here four light wooden frames, hinged together; two of them are 10 inches by 20 inches and the others are 10 inches square. These are covered with paper, and may be taken to represent portions of the planes of projection as seen in the first angle. I have here, also, a wooden model of rectangular shape, mounted on a stand. The surface of this model is diversified by certain irregularities, depressions and projections. (See Fig. 1.)

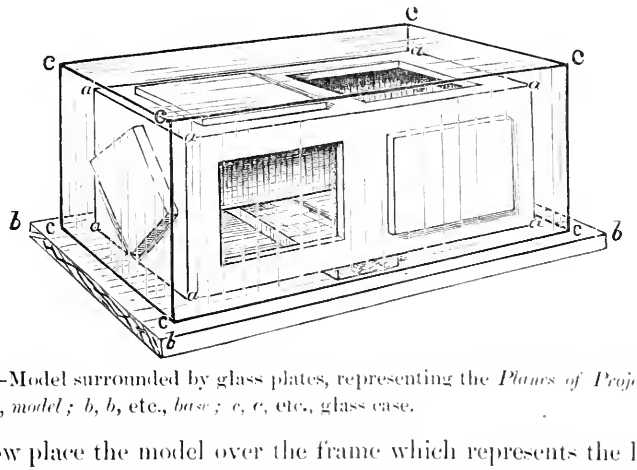

FIG. 1.—Model surrounded by glass plates, representing the *Planes of Projection.* *a*, *a*, etc., *model*; *b*, *b*, etc., *base*; *c*, *c*, etc., glass case.

I now place the model over the frame which represents the horizontal plane, and at a distance from it of one inch, and fold around it the other planes, each being one inch distant from the side of the model,

which now appears as though viewed in the first angle. Now, we are taught that this model is to be drawn by imagining every point represented in each plane by the point in which a perpendicular to the plane passing through the given point in the model would cut the plane; that is to say, a number of perpendiculars from the front of the object will form its projection upon the vertical plane, perpendiculars from the top will form upon the horizontal plane its plan, and in the same way a view or projection of the left end of the model will be formed upon the side plane on the right hand. Supposing the projections made, we proceed to reduce them to one plane by folding the side plane off to the right and the horizontal plane downwards, and then, as you see, we have a drawing of the model in which the views are arranged thus: before us we have a front elevation, below it we see the plan, and upon the right hand we have an elevation of the left hand and of the model. (Fig. 2.) This is the method usually taught

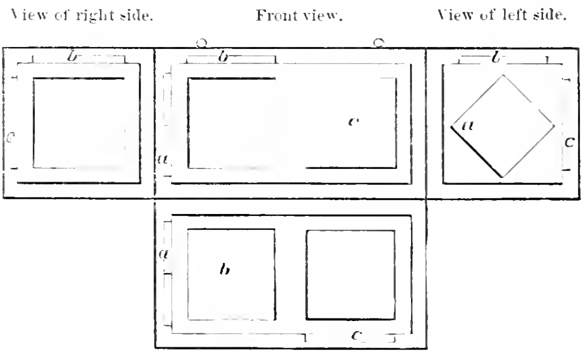

FIG. 2.—Frames covered with paper to represent the *Planes of Projection*, showing a drawing of the model made in the "1st Angle." The parts of the model are represented in the different views by the same letters, *a*, *b*, *c*, etc.

in schools and set down in most of the books, except that the revolution of the planes is of course an imaginary operation.

This method, too, is employed, I believe, generally, if not almost universally, in continental Europe; but in England and America a different system has long been in vogue, which, while quite as correct mathematically as that I have shown, has certain practical advantages which make it by far the preferable plan for use in working drawings. What is considered the practical method we may illustrate in a similar manner; but let us substitute for our paper planes corresponding

sheets of glass, hinged together, and let us arrange them differently; that is, we put the horizontal plane above the model instead of below it, and the vertical plane in front instead of behind; in the first method we in fancy looked through the model at the planes, *i. e.*, paper; we now reverse this, and look through the planes at the model, and we have simply to trace upon each plane the lines of the object which we see. (Fig. 1.) Having done this, we again unfold our

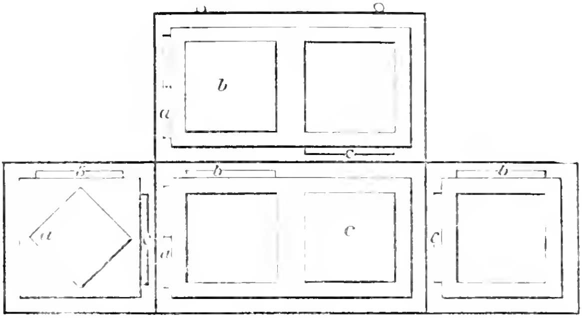

FIG. 3.—Glass case (see Fig. 1) unfolded, showing a drawing of the model made according to the "Common Sense" method. The different views of the same parts are adjacent to one another.

frame, by lifting the horizontal into the vertical and bringing out the side plane, and we have a side elevation with a plan above it, and an end elevation next the end which it represents; or, in other words, our drawing appears exactly as though we had made a cardboard model of the outside of the object, and had laid the sides down on the table so arranged that by folding them they would form a solid of the shape of the object. This, I submit, is the natural, convenient and correct disposal of these views, and I think we can the better appreciate this arrangement if we drop the misleading words, *plan* and *elevation*—terms which we have borrowed from architectural drawings. In very many mechanical drawings, especially detail-drawings, almost any side may be taken as plan or elevation with equal propriety. Perhaps we associate the idea of altitude with the term "elevation," and have an instinctive feeling that the "plan" should appear below it; but in point of fact what we call the "plan" in mechanical drawings is generally a top view, or one looking down on the object from above, and hence properly put at the top of the sheet, while the space below is

reserved for a bottom view, or one looking at the object from beneath, and such a one may be extremely important. Less confusion of ideas would result from the systematic use of the words—top view, bottom view, front and back views, and end views.

The plan recommended by the Descriptive Geometries is not bad when the object is simple; indeed, for the purpose of studying the principles of drawing scientifically, I see no reason why it is not the most convenient method to follow; but it seems that certain inconveniences develop as soon as we leave the cones and cubes with which the mathematician illustrates his reasoning.* For example, take a drawing of a locomotive—a complicated machine, which, even when reduced to a small scale, must occupy a comparatively large sheet of paper. When we want to see a view of the smoke-box door in front of the boiler, is it natural or proper that we should go to the end of the tender to find it? And when we want to see a view of the cab roof should we look for it under the driving wheels? Now, with all deference to what has been considered the scientific method, I contend that it is easier and better, and quite as correct mathematically, to put the views of a drawing nearest the part represented, or, speaking in the language of Descriptive Geometry, to draw the object in the third angle, viz., that below the horizontal plane, and behind the vertical.

The front elevation is almost always the view which carries the largest number of dimensions and shows the most parts, hence we put it in that part of the drawing where it can be most readily consulted; in the plan, or top view, we want to show the general arrangement of the parts; it usually has but few dimensions, and we easily look up to consult it; while in drawing the end views it is manifestly much easier and more mechanical to project from the right hand end of the object to an end elevation on the right hand of the board, than it is to carry all these lines over to the left hand end of your drawing board. That is, the shorter the distance between the two views of the same parts, the easier, the more convenient and more accurate are the operations of projecting with straight edge or T square. In arranging the various oblique planes which may be needed to show parts of the surface we have simply to follow the same rule—we draw the view as it would

* Further thought on this subject indicates that this assertion should be qualified, and I am now disposed to think that investigation may possibly demonstrate that the whole subject can be as well taught by abandoning the intersecting planes and substituting the "glass box" conception.

appear through a plate of glass held parallel to the surface we wish to show. Take, for example, a truncated cone (Fig. 4). The horizontal and vertical planes do not show us the true shape of the elliptical surface of the top of the cone. To show this we make a view on an imaginary plane parallel with this surface and immediately over it, and in placing this view we follow precisely the rule that governs the arrangement of the others (Fig. 4, *a a*). Were we to adopt the other method we would be obliged to project the ellipse through the cone to a plane below it, as shown in Fig. 4, *a′ a′*.

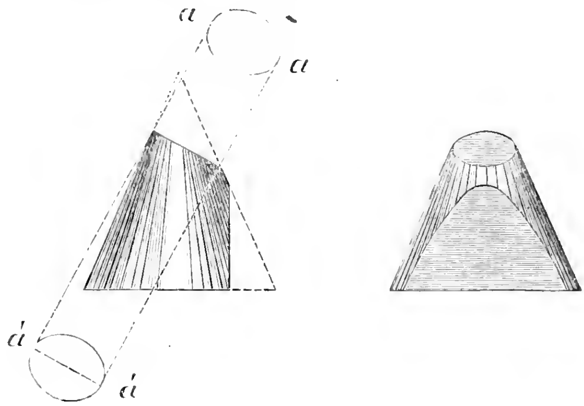

Fig. 4.

Let us take another illustration: a draughtsman at a large shop in this city was called on to draw a turning lathe, and, following the teachings of his school days, he arranged the various views as I have shown in a rough sketch on the blackboard, that is, he drew a front elevation, below that he drew a plan, and adjacent to the live head he put a view of the poppet head; while at the other end of the drawing was a projection of the live head. Now what was the result? The long legs supporting the lathe-bed—of little importance as far as dimensions are concerned—occupied the centre of the board, separated the plan and elevation of the bed, and, as in the case of the heads, the different views of the parts were as remote from one another as possible. The arrangement of the various views in a drawing is not simply a matter of preference or taste: it is a question of real practical importance. Perhaps if skilled draughtsmen alone had to do with drawings—or if draughtsmen would or could in all cases make their drawings as full and complete as possible—there would be no need to

discuss the matter, for, as I said, either system will show the true shape of any object if carried out logically and fully; but drawings pass into the hands of artisans who are rarely familiar with the rules of Descriptive Geometry, and for whom drawings should be arranged in the simplest and most easily comprehensible form. Then again, drawings cannot always be perfect, and it may be, indeed often is the case, that some detail is shown in but one projection; it then becomes a matter of grave importance that the stand-point from which the drawing was made should be clearly known. I think that it is in cross-sections that this ambiguity is most apparent. Suppose, for instance, that a section of a boiler is shown, and the arrangement of the tubes in this boiler are set forth only in this one view; suppose these tubes, for some important functional reason, are not arranged symmetrically about the vertical axis, but that there is, for instance, one more tube on one side than on the other—now whether that tube will be put in the right side or left side of the boiler will depend upon which system of projections was used. No one can be long in the draughting office of a machine shop without becoming sadly conscious of the readiness with which drawings are misunderstood, and of the curious fact that if a dimension in one place, or one view of half a dozen is wrong, somewhere in the process of manufacture that wrong figure or faulty view will inevitably be followed. People rarely pay much attention to these things until an expensive blunder is traced to some half-made drawing, and then the question is generally settled. In this way it has come to be, I think, without doubt, the almost universal custom in shops in England and America to arrange the views in what I have described as the practical or common sense method. This is, perhaps, strictly true only as regards the front and side views, for probably a majority of those who use the "common sense" arrangement here will inconsistently place the top view below the front. Some draughtsmen hold that the position of this view is merely a matter of convenience, and that its relative importance should determine its location; while others contend, with greater show of reason, that one inflexible rule should determine these positions, and that what is right in one case must be equally so in the other.

The Descriptive Geometry method is taught, I presume without exception, in the most noted European schools, and I understand is practiced generally in foreign machine shops; but even there neither plan appears universally adopted, and we find in text-books and else-

where drawings made each way. I have here tracings made by a distinguished professor in a foreign technological school which conform perfectly with our shop practice, and in Prof. Reulleaux's "Der Constructeur" many of the illustrations also accord with our ideas. I have here, too, some plates exhibited at the Centennial Exhibition by the French Department of Public Works. They are drawings made for use in the imperial schools. We find among them some in which the side elevations are placed exactly in accordance with American shop practice: the plans are invariably and inconsistently below the elevations. Indeed, among those who profess to be our authorities in England and America the same indecision exists. Here are a number of illustrations taken from an English work published about 1852 or 3, and we find both kinds of drawings among them. In our text-books the same state of things is apparent, and probably most of our schools teach the European method.

Our two leading schools of mechanical engineering, Cornell University and Stevens Institute, teach the Anglo-American, or, as I prefer to call it, the shop plan, and insist upon it strongly, while in the drawing schools of the Spring Garden Institute and the Franklin Institute the same ground is taken. Now, one difficulty which results from this division of opinion is this, that we rarely take up a work on mechanical drawing—Church's for instance—without finding drawings made both ways, and therefore whenever a mechanical drawing is presented, we must first analyze the different views until we find from just what stand-point each was made; and this is repeated by every man who examines the drawing. If, then, in a machine shop there are drawings made both ways, every workman, pattern-maker, foreman, fitter has to go through this process with a manifest loss of time and risk of error.

A few days ago I met a recent graduate of one of our leading scientific schools, who is now employed as a draughtsman in a large manufacturing establishment, and this subject being uppermost in my mind, I inquired of him what plan was followed by his employers. He described the usual shop plan, and said that it was rigidly enforced. I then asked him if he had been familiar with that plan before he began work in his present position, and whether he had been so instructed at college. He immediately replied:—"Why, ever since I've been at work I've been trying to unlearn the method I learned at college."

Now this furnishes a text upon which I should like to enlarge a little, especially as his experience corresponded precisely with my own, and with that of every college man of my acquaintance, who has gone into the shops. I, too, learned at college the Descriptive Geometry method of arranging the projections in a drawing, and as soon as I attempted to apply it in the shop I was taken to task for making indistinct drawings.

The value of education of a special character for those intending to become engineers is now widely recognized, and our colleges, almost without exception, are endeavoring to meet this demand by the establishment of departments devoted exclusively to teaching in the various branches of engineering. Large sums have in many cases been expended in the erection of proper buildings, the equipment of laboratories and workshops, and from these schools hundreds of young men are annually graduated, and go out to find employment, feeling that they have at least laid the foundations of a thorough training in the professions they intend to follow. If such a young man finds that the teachings of his Alma Mater differ from the practices of the workshop or engineering office, that the methods he has learned at the expense of so much pains and time are regarded on the one hand with contempt as obsolete, and on the other, perhaps, with derision as impracticable or "too scientific,"—for your old-time machinist is frightened at the mere mention of the word—if, I say, the college man finds he and his college differ from the shop, he concludes at once that the shop is wrong; but if after a fair trial in any particular case he is compelled to admit that the shop ideas are correct, he feels a little indignant that he has wasted time in learning that which he has now to unlearn, and his respect for his college and the wisdom of his teachers just that much decreased.

I do not wish to disparage the value of Descriptive Geometry, or the indubitable importance to the engineer of a thorough scientific education.

Descriptive Geometry is only the expression of the principles of mechanical drawing in scientific form; no draughtsman can work without applying these principles at every step, although he may not be aware that they have ever been scientifically formulated.

But while urging the value of science and education, I wish to emphasize the opinion that the instruction of the schools should conform to the best shop practice, especially when, as in the case of pro-

jections, the superior advantages of what Prof. McCord—perhaps the best American authority on mechanical drawings—describes as the "common sense system of making drawings," can be so easily demonstrated. Those who have a pecuniary interest involved in a branch of manufacture can generally be relied on, in the long run, to adopt that which is best fitted for their use; but if our instructors are not prepared to endorse what the makers and users of drawings tell them is practically best, is it asking too much of them that they should at least describe to their students the various plans in use? If they, on the other hand, allege that they do not know the practice of the shops, may we not justly say that it is their business to inform themselves?

In the present case the "common-sense" system can be so easily demonstrated to be the better, that it appears somewhat strange that it is not taught by *all* of our schools and colleges. In this connection I may cite, as typical cases, the experience of two prominent Philadelphia concerns. At the Baldwin Locomotive Works so much trouble was caused by misunderstanding drawings, and so many mistakes occurred, that a positive rule was at last put in force that all drawings should be made with the views nearest the stand-point from which the view was supposed to be seen; and, for their guidance in cases of doubt, the workmen were instructed to bend the drawing backwards between the two views, the doubtful one and the one nearest it, when its true relation would at once appear.

Again, Wilson Bros. & Co., the prominent firm of engineers and architects, have found it a decided advantage to make such of their drawings as are intended for the shops in accordance with the usual American shop plan.

We are taught in most of our text-books to draw any object we desire to represent by referring it to a "ground-line," which is the intersection of the vertical and horizontal planes; and we learn that the distances of the views above or below the ground-line mark the distances of the object drawn from the planes of projection, and other facts of equal value; for instance, we are told to project our dimensions from one view to another by a system of parallel lines and arcs, but, so far as I am aware, mechanical draughtsmen never draw in this way. The intersection of the planes of projection is never regarded for a moment, and I fear that many of our best mechanical draughtsmen are entirely unfamiliar with even the terminology of Descriptive Geometry, which, however valuable it may be as a mental exercise, is

by no means a necessary preliminary to a pretty thorough knowledge of mechanical drawing; and, in fact, it seems to me to hamper with unnecessary difficulties a very simple subject.

This is especially the case in such a school as that of the Franklin Institute, which is designed to meet the wants of those who are actually engaged by day in the practice of some mechanical pursuit, and many of whom have had very limited school education. With such scholars it seems clear that the general principles and practice of mechanical drawing can be taught more directly and clearly than by following in detail the course of reasoning laid down in the geometries. These start out with the consideration of the position of a mathematical point as situated in space, and proceed from thence to the location of lines, planes, and finally solids, forming thus a logical sequence which, however, demands on the part of the learner an amount of mathematical training or familiarity with mathematical modes of thought, which we must not look for among the pupils of the Franklin Institute or the apprentices in a mechanical drawing office.

The usual method of procedure in making a mechanical drawing differs in many respects from that generally recommended in the books, and is probably based on the requirements of practice. Thus, drawings are usually made with reference to centre lines. In beginning a drawing a horizontal line is generally first drawn, and then a perpendicular to it; the first may be one edge of the object, its ground line, or an axis through some important part, according to the nature of the thing drawn. Suppose we were about to draw the lathe I have shown in my sketch on the blackboard. We should probably first draw the floor line, then at a known distance a line passing through the spindles, and this would be our most important centre line or axis. On these lines and on perpendiculars to them we should measure off the coördinates of the different determining points, that is, their distance from these axes, and join them by the necessary lines. We may measure these distances with the scale or step them off with the dividers, just as we please, but we object to confusing our drawing with a lot of broken projection lines, and we should arrange the views just as the shape of the object and the size of our paper require, and never think for a moment of planes or ground line. We should put in just as many views as may be required to show the object with perfect clearness, if it takes twenty; but if one is enough to show our meaning without doubt, then let us make no more, but whether we have

two or twenty views, let us follow in their arrangement one system only. Let the mechanic understand clearly that he will always find these views in the same relative positions.

The great number and variety of parts in many mechanical devices often render mechanical drawings extremely complex, and great care and judgment must be exercised to show all that is necessary without confusing the drawing with a multiplicity of lines. To increase the clearness of drawings, one "convention" in common use is what is known as "line-shading," which originally consisted in strengthening all lines representing surfaces not illuminated by the direct rays of the sun. The light was supposed to come from over the left shoulder of the draughtsman at an angle of 45° elevation from the horizontal plane, and an equal inclination to the vertical plane; then objects were shaded as shown in Fig. 2. But gradually this has been changed, and we now assume that shade-lines on the right and lower sides of an object denote a raised surface; on the upper and left hand they mean a depression. An appearance of solidity is thus obtained, and a single glance serves to tell us whether a part is raised above or sunk below the general surface, while we have no need to ask ourselves if the view we examine is plan or elevation.

The other great advantage of "line-shading" is that it gives character to a drawing and relieves the sameness produced by lines of even thickness. Many draughtsmen accomplish this by brush-shading parts of a drawing. It is generally impracticable in mechanical drawing to thoroughly shade all parts, but by tinting parts, for example, the forgings blue, and shading them a little, they are at once brought out of the drawing, eliminated as it were, and it becomes proportionately easier to follow the rest.

It seems scarcely necessary to allude to the subject of figuring drawings. It is now happily admitted on all sides that a working drawing should have all the necessary dimensions marked in figures, and that no workman should be allowed to measure a drawing. The privilege may be allowed the pattern-maker in minor details where surfaces are not to be finished, but distances between centres and all dimensions for finished surfaces should be set down on the drawing, and followed absolutely. I am aware that these views are not entirely general, for I observe that a recent writer on the subject pleads for wooden models of all the parts of a drawing, "because," says he, "it is so difficult to set your calipers to the lines on a draw-

ing." I have no doubt *he* is the kind of a man who will talk about a size as being "little full scant"—an individual about as mechanically worthy of respect as the man who, when he wanted a door to fit a door-way in his house, converted his arms into a pair of calipers, and walked off to the carpenter's with his hands in the air, his elbows glued to his sides, and the size of the door between his outstretched hands.

As outside views will not usually show everything about the object drawn, we have recourse to cutting it by one or more imaginary planes, and thus presenting cross-sections of the various parts. In the disposition of these cross-sections the principles that determine the position of the elevations must be observed. If we put an elevation of the right hand end of the object adjacent to that end, and draw it as though we stood at that end and looked towards the left, then cross-sections parallel to that view should also be placed at that end and be drawn as though our point of view was the same, and as if the intermediate portion of the object, that is, all parts between us and the section plane were removed.

To distinguish projections of this kind from outside views, we have recourse to one of two conventional modes. We either tint them a color which we decide is to represent the material to be used, or we "cross-hatch" or "section-line" them, that is, mark the surface of the imaginary section with a series of parallel lines inclined at an angle of 45° with the horizontal and vertical lines; these lines we make of various colors indicative of the material represented. Thus black lines indicate cast iron; red, brass, and blue, wrought iron or steel, while if the drawing be tinted a light tint of India ink or of neutral tint, it is usually taken to signify cast iron; yellow, brass; blue, wrought iron, and purple, steel.

Of course, architects and other makers of constructive drawings adopt other colors to represent the different materials with which their drawings deal. Section-lining has the important advantage over tinting that it serves to separate to the eye the various pieces of which the machine in section is composed; for by simply inclining the lines in adjacent pieces in opposite directions the various parts are at once distinguishable. Of course care must be taken not to change the direction of the cross-hatching in the same piece.

I have said that we denote the different materials by differently-colored section-lines or brush-tinting; but the now general use of

blue prints necessitates a modification of this plan. In the first place color does not show in the print in any way except as a shade of blue or bluish white, varying only with the opacity of the colors. Hence we must for sections use cross-hatching, and as colors will not serve to distinguish different materials, we have recourse to a different arrangement of lines, thus: equally spaced lines may denote cast iron, lines grouped in twos, brass, and if arranged in threes, wrought iron. In these conventions each shop is a law unto itself only, and no unanimity exists among them.

In urging the necessity that exists for extending the knowledge of mechanical drawing, as useful, in fact imperatively necessary, not only to the draughtman, architect, engineer or designer, but to every artisan, mechanical pattern-maker, blacksmith or carpenter, or other handicraftsman, who is or may be called on to work to drawings. In urging, I say, the vast importance to us of this branch of education, I do not wish to disparage for a moment the value of free-hand drawing. In fact, I would not restrict the term mechanical drawing to that done with instruments and to an exact scale. A free-hand sketch may be a mechanical drawing if it be a constructive drawing, that is, if it so represent on a flat plane the size or shape, proportions of something to be constructed, that it will serve to impart the proper idea to the man who is to make it.

I have often observed a tendency among persons absolutely ignorant of drawing to put their graphic explanations in the form of rude attempts at perspective drawing; that is, they try to draw things as they see them, but also try to show details of construction which they cannot see, and the result is generally a monstrosity which tells less of the true form than a less ambitious and more easily made sketch would if the maker knew anything of mechanical drawing. A knowledge of free-hand drawing is of the greatest value to all who have to do with mechanical drawings. In fact, facility in off-hand sketching is of perhaps more practical value than great dexterity in the use of instruments at least to all but the professional draughtsman. Men who make the neatest and most accurate drawings often cannot make a presentable free-hand sketch, while those who do both well, find their skill has a proportionate market value.

A recent writer says: "The object to be made must first be clearly conceived in the mind, then portrayed correctly in a drawing, from which the artisan learns how to make it." Now this is not, I think,

strictly correct. It is seldom that a clear mental conception of a complex device can be formed at once. The idea at its inception must be crude and vague, and to attempt to arrange its details mentally is analagous to the effort involved in the solution of an algebraic or geometrical problem without the aid of pen or pencil. The designer must think, pencil in hand, and under his facile fingers sketches grow, are changed, erased and recommenced, as the obstacles to be overcome, and the faults in the design are developed by the graphic representation which accompanies the mental process and serves to record each step.

As I have already had occasion to remark, a knowledge of the principles of drawing is of primary importance to the artisan, the mechanic, as well as to the draughtsman or designer. Unfortunately our public school system does not recognize this fact, and proper instruction in drawing is not given, as it should be, with lessons in reading and writing; and even in those schools which attempt to teach it, we rarely find it adequately or thoroughly done.

Now, it is in a measure to supply the lack of this kind of instruction that the Franklin Institute Drawing School was established, and we can have no better argument in proof of the fact that it supplies a real and recognized *want* than is found in its remarkable growth; its classes are constantly increasing, and from 75 students two years ago the attendance has grown to over 160 at the present time. Of this large number over 120 are actually engaged in the practice of some mechanical pursuit, that is, they are machinists, pattern-makers, draughtsmen, etc. How are we to account for this large attendance except by assuming that the value of drawing is becoming recognized, and that students know that here drawing is taught by practical draughtsmen and according to methods in actual use? In regard to the questions upon which the doctors disagree the Institute School takes no middle course, but teaches boldly and clearly those methods and conventions which practice has demonstrated to be the best. And it seems to me that the Institute might with advantage go still further and attempt to assimilate the differences in practice to one common standard, formed of the best parts of all systems. In this way, perhaps, a Franklin Institute Standard of Mechanical Drawing might be established, which would tend—as in the case of screw threads—to uniformity in shop practice.

The drawings of any establishment, however, must always have an

individual character, which is determined principally by the shop standards and facilities, the gauges, the reamers, taps, mandrils, and other special tools and appliances with which that particular shop may be equipped. The draughtsman must be guided by a knowledge of what the shop has and what it can do, and must arrange his drawings with these facts constantly before him. Drawings fitted for one shop might, therefore, be far from right for another shop, but this is no reason why a drawing made in one shop should not be perfectly understood in any other.

I feel, ladies and gentlemen, that this has been merely a cursory and superficial review of the subject, and I am afraid you have found it a dry one. But if I have succeeded in impressing any of you with the really vast importance of drawing as a branch of education, more or less useful to all men, and also with the necessity that it should be taught in the schools as it is used in the shops; if, I say, I have made this clear to you, I shall not, I am sure, have bored you in vain.

Needle Making.—At Borcette, which is the most important centre of needle manufacture in Europe, the conversion of the steel wire into rough needles requires 20 operations; the principal of which are the measurement of the wire, the scouring, the winding off, and the cutting into lengths equal to two needles. The pointing is done with two grindstones. By the aid of a copper finger-stall the workman holds 50 wires at a time, which are heated to redness by the friction. The dust and powdered steel formerly produced consumption in the workmen after a few years, but by the aid of ventilators this evil has been entirely overcome. After the sharpening, boys cut the wire in two, flatten the head, anneal and punch the eyes. The tempering and annealing require nine operations, but they are done in piles of 15 kilogrammes (33·69 lbs.), containing more than 300,000 needles. One million needles are polished at one time. There are five operations, which are each repeated seven or eight times. The needles are put in hollow rollers with small hard stones and colza oil. The stones are gradually pulverized, and the friction of the powder gives the principal polish. For the final polish oil and coarse bran are used. The sorting of the polished needles requires five operations, and after the burnishing they are put into papers.—*Revue Industr.* C.

THE APPLICATION OF FRICTIONAL ELECTRICITY TO THE PURIFICATION OF MIDDLINGS.

By Robert Grimshaw.

Abstract of a paper read before the Franklin Institute, October 19, 1881.

For the benefit of those not present at my lectures before the Franklin Institute last winter, upon Modern Milling, I crave the indulgence of those who then honored me with their attendance, in order that I may give a brief and general outline of what constituted old-fashioned milling, and what are the changed principles which go to make up modern milling.

Wheat, from which is made most of the flour we use, is a berry formed of two lobes, between which there is a lengthwise crease. This berry consists for the most part of white starch granules, surrounded by white layers of cells containing a large proportion of gluten, which is nitrogenous, and the entire mass enveloped in thin brittle coats of brown woody fibre, called bran.

There is also a small, waxy, yellow germ, very nourishing, but discoloring to the flour.

Wheat is bought by weight more often than by measure; and the farmer is not careful to remove from the berries the oats, grains of cockle and other seeds, chaff, chess, sticks, straws, gravel, sand, etc., which are mixed with the berries; nor to remove from the face of each grain the very fine dirt adhering thereto. Still less is he careful to rub off the beard or fuzz found at the end of each grain, and to brush out the bluish crease dirt packed away between the lobes. These little trifles the tiller of the soil leaves to the one most interested—the miller.

While the object of milling (outside of that done by those who advocate the bran as food) is to get all the starch and glutenous cells in the shape of fine, sharp flour, free from all bran particles, grease, dirt and other foreign matter, and to get the bran in as large scales as possible, free from adhering or intermixed starchy and glutenous granules,—the old-fashioned miller (and by him I mean nearly every miller up to fifteen years ago, and many of the present day, of the type who believe that a water wheel runs faster at night than during the day,) goes at this task in this way:

First, by screens and wind currents he takes out all loose impurities, heavy and light, except bits of iron and steel wire, which last are removed by magnets in the spouts. Then, by rubbing the berries among themselves between revolving drums and a perforated sheet metal case, all the while subjected to a current of air, which rubs off and blows away the fuzz and most of the surface dirt. With a brush machine he gets out most of the bluish crease dirt. If the weather be cold (or even in warm weather certain grades of wheat with bran that is very brittle) he toughens the bran by means of a steam heater. While the grain is yet warm he passes it between two revolving horizontal mill stones; the faces of these mill stones being made perfectly plane, kept in parallelism, and dressed to a nicety, with furrows and smooth faces determined by the character of the stone and wheat and by the whim of the miller. The result of the friction and pressure between the smooth plane surfaces, and of the cutting by the edges of the pores and of the furrows, is to grind the berries into a mass called "chop" or "Graham," composed of bits of broken berries called "middlings," flour in starchy powder, germs, and bran scales having middlings and flour sticking to them.

In old-fashioned milling the chop was separated by sifting in inclined revolving cylinders having walls of fine silk of fineness varying from head to foot, into middlings (or bits of wheat), bran, and flour proper. But the middlings had flour and very fine bran mixed with them; the bran had some middlings and flour adhering to it, and the flour contained very fine bran particles. The bran was either passed between mill stones to rub off some of the middlings and flour, or sold for feed without cleaning. The flour was divided, by bolting, into grades of varying fineness, color, and "strength" or doughing capacity. Those portions of the flour which contained most gluten cells were the "strongest," in two senses: *First*, they would make more dough and more bread, per 100 pounds, than those portions having less gluten; for gluten absorbs more water than starch does. *Second*, they would make more muscle and be more strengthening and more nourishing than the starchy flour. But the middlings, although containing more of the gluten cells than any other portion, and hence entitled to the most distinguished consideration, were, metaphorically speaking, thorns in the side of Mr. Dustycoat. How were these particles of bran, so fine as hardly to be distinguished by the naked eye, to be taken out from the middlings? It must be borne in mind that

these bran particles, which would not only lower the percentage of the nourishing parts of the flour, but (more important to miller and merchant) injure its beautiful white color, are just as fine as the flour; hence sieving would be of no use. So the middlings were either sold as feed at so much a ton, or run back into the eye of the mill stone to be ground up with the wheat, the miller trusting to luck to get more good white stuff into the flour than he put worthless dark stuff in.

Such being the conditions, the enterprising miller endeavored to make as few middlings as possible; and with this object dressed the surface of his stone so that there would be about one-third in furrows and two-thirds in the "lands" between. This left plenty of rubbing surface, and ground, rather than granulated, the berry. The furrows were made deep, say one-fourth to one-half inch for a four foot stone.

But as things are now, under the more enlightened practice of modern milling, the despised middlings, the skeleton in the closet of the miller, have become his chief desideratum. And why? Because some one (to whom the milling world should erect a statue in like manner to that in Boston to the unnamed discoverer of anæsthetics) found that it was possible to get out of these middlings even the finest discoloring matter; and although such methods have been employed gradually for many years, it is not until the last ten or fifteen years that machines by which middlings were purified have been in the market, doing satisfactory work, and selling at reasonable prices.

There are two types in general use where modern milling is employed: the sieve and air current machines, and the centrifugal. In the first, the unpurified middlings are passed down an inclined sieve cloth with bolting silk of increasing coarseness, and having an endless shake. Through the downward traveling mass of middlings and bran a carefully graduated current of air passes. The impurities are blown up and away, the fine purified middlings pass through the screen, and the coarse stuff tails over at the end. In the centrifugal machine, advantage is taken of the different specific gravities of the particles of bran and those of middlings, and the mixed mass is thrown out from a revolving central discharge, across ring-shaped currents of air; the different grades of material falling down ring-shaped spouts at different distances from the centre and being carried to where they are desired.

The purified middlings, no longer despised, no longer sent back to the wheat stone to be run in common with the whole berries, are

treated with royal honors, and given to special devices for making from them the well-known "patent" flour. The stone for middlings grinding should best be of hard texture and close grain, because there is no need of the cutting edges of large pores; and smaller mill stones may be employed than for wheat grinding.

The aim being to get as many middlings, and to have these as large and sharp, as possible, attention has been paid to the construction of devices for granulating the wheat with a view to the production of middlings as a specialty. One device was to employ a series of several mill stones, the first pair set so far apart, and dressed so coarsely, as merely to crack the wheat, the next pair being set closer, etc., the berry being gradually reduced into middlings, bran, and a little flour of rather poor grade. Between each two breaks, or reductions, these three elements were separated by rotating reels suitably clothed with wire-gauze, or with silk. This system of granulation constitutes gradual reduction by mill stones. It is not, of course, adapted to small mills; for the necessity of having three to five sets of breaking burrs prevents its adoption in mills having less than ten sets of burrs.

A more advanced practice is cylinder- or roller-milling. In this system, instead of employing for granulation large, flat, circular surfaces, of which those portions near the circumference pass each other at a higher speed than those near the centre or eye, there are used cylinders revolving either together or against a breast or concave; and by these the grinding is effected, not by contacting surfaces with varying speeds, but by a simple line of contact, of which all parts have the same grinding speed.

For breaking the wheat into middlings, and for bran cleaning, these rollers are generally of chilled iron, running in pairs, with from eight twisting grooves per inch of circumference for the coarsest breaks, to thirty for the finest.

For flouring the middlings, unglazed porcelain rolls are used. For flattening the germ, and bringing the middlings to regular sizes, plain chilled iron rolls are employed. There are also used single rolls of stone working against stone or against iron breasts, and single iron rolls working against adjustable iron concaves.

These cylinder granulators make more, better, and sharper middlings than the burrs, heat the chop less, and do not break and cut up the bran so much as the burrs. Besides this, they take up less room and consume less power, and are by all means the best for mills making

over one hundred barrels of flour per twenty-four hours, especially from hard spring wheat, which has very brittle bran and is rather difficult to handle with burrs.

Saying but little of the bolting process, for which we have but little time, we come at once to the purifier, which as a class is *facile princeps* the king of milling apparatus.

I shall first show upon the screen one of the best as well as one of the most recent wind purifiers (the Case), in which, as you will see by the general view and the lengthwise vertical section thrown upon the screen by Mr. Holman, there are two separate screens, one above the other, each with its separately adjustable wind supply. The unpurified middlings having been fed to the upper end of the first screen, by a specially contrived feed box, designed to distribute the middlings at a uniformly regular rate, and evenly upon all portions of the width of the screen, pass along over the fine cloth, receiving a lengthwise jarring action as they pass from the fine to coarser cloth, and being held up in suspension by the currents of air from below, which carry away the light and worthless particles and let the sharp, fine middlings go through the meshes of the silk, while the coarse matter and germs tail over at the end.

I now come to the electric purifier, which instead of employing air currents to lift up and hold in suspension the particles of bran fibre and other impurities, calls into operation the attractive power of frictional electricity. One of the most familiar lecture experiments of our school-boy days is the rubbing of a stick of hard wood, rubber, glass or shellac with a woolen rubber and causing it to pick up small light particles of paper, hair, etc. The friction caused the generation of frictional electricity, which was called vitreous or resinous, according as the excited substance was glass or resin.

The machine consists of a sieve to effect separation by size, and hard rubber rolls, revolving against sheepskin rubbers to excite electricity, to effect separation by weight; the whole mounted in a suitable frame.

The sieve is on the top of the frame, and below it are the necessary conveyors to remove the purified middlings which pass through the sieve, and slides to separate them as desired by the miller.

The hard rubber rolls are each nine inches long and six inches in diameter, three being placed upon one shaft, and the shafts being fourteen inches between centres.

The rate of revolution is about thirty turns per minute, which causes

the bran and the lighter impurities to rise above the heavier portions, and within the attractive influence of the rolls. At the head the sieve is clothed with, say four or five feet in length, of a No. 8 cloth (having 7059 meshes to the inch), through which the very fine middlings pass with the flour dust. For the first operation the numbers of the cloth of the screen increase in coarseness from No. 6, having 5184 meshes to the square inch, to No. 0, having 1444 meshes per square inch. For subsequent operations the clothing should be finer, running down to as fine as No. 2 (2704 meshes) at the tail for the last operation. The work of the electric part of the apparatus commences about two feet from the head of the machine. The bran and the impurities being lifted up and taken out by the electric action, the pure middlings are shaken through the sieve according to their size, and may be run together, or separated according to size, at the will of the miller.

It is better that before purification the middlings be graded according to size, because if the machine be clothed and adjusted for one size it will not work as well upon another, or upon several sizes mixed. It will pay to grade in all cases where "middlings milling" is practiced, and the capacity of the mill is over one hundred barrels per twenty-four hours.

The frame of the purifier is ten feet long, four feet high, and three feet wide, the sieve having a cloth surface composed of three strips each nine inches wide and nine and one-half feet long, over which there are eight rolls. The bolting surface of twenty-one square feet is rated at a capacity of 500 to 600 pounds of middlings per hour. It will be noted that in the ordinary wind purifier, in which the particles of bran are lifted by the air current passing through the sieve cloth, and impelled either by a blast fan or an exhaust fan, or both, there is trouble from the particles clogging the under side of the cloth, rendering it necessary to free the machine by some special device, generally a traveling brush, although knockers, whips, rubber balls, etc., are used. The electric purifier requires none.

The power required is stated by the makers at about one horse-power per 1000 pounds of middlings per hour, that is, about one-half horse-power for each machine.

One of the most objectionable features of wind purifiers is the necessity of having some receiver for the fine dust blown from them—there being generally a dust-room or stive-house, which is especially

liable to fires and explosions. The electric purifier making no dust, requires no dust-house or dust-collectors.

To get down to the details of the system, we will first consider what is required for a small mill of 75 to 80 barrels capacity per twenty-four hours. We will assume, in the first place, that by neither the wind nor the electric system can middlings be thoroughly purified with less than three operations: that is, without some portion of every lot of middlings passing three times over a sieve. Where the capacity of a mill is as large as 225 to 250 barrels of flour per twenty-four hours three machines are needed. Where the capacity is as small as 75 to 80 barrels per twenty-four hours there is used what is called a "combination" machine, which is practically three purifiers in one.

The "combination" machine has rubber cylinders and sieve the same as described above. It differs, however, in that the feed hopper is divided into three sections, corresponding with the three sieve sections. The first section of the sieve, for coarse roller mills middlings, is clothed with 8, 3, 1, 0 and 00 silk; the second with 8, 6, 3, 2, 1 and 0, and the third with 8, 3, 2 and 1. The ungraded middlings are spouted directly to the first section of the feed hopper and thence on to the first sieve section. There are underneath the first and second sieve sections two conveyors each, the upper conveyor spouting directly to the flour-stones or rolls, and the lower to an elevator which discharges into the next section of the feed hopper. Under the third sieve section is one conveyor, spouting, with the upper conveyors of the first and second sections, directly to the flour stones or rolls. Sweeps are arranged to run through the offal troughs to keep the first section offal separate from the second and third sections. A spout is arranged to take the tailings of the sieve from all sections to the smooth rolls.

So, when we come to the use of this machine, the middlings passing over the first sieve section which fall through the 8 cloth are finished, and go directly to the flour rolls spout by the upper conveyor, while those falling through the rest of the sieve are carried by the lower conveyor to an elevator, which discharges them into the second section feed hopper, *en route* for the second sieve section. All the middlings in this section passing through Nos. 8, 6 and 3 cloth are finished and are conveyed by the upper conveyor to the spout that leads to the flour stones or rolls, while those passing through the remaining portion of the sieve are conveyed by the lower conveyor to the elevator and by it discharged into the third section of the feed hopper, which in turn are

fed on to the third section of the sieve. The middlings passing through the whole length of the sieve of the third section are purified and conveyed to the spout that leads to the flour stones or rolls.

The tailings from all sections are spouted to smooth rolls for flattening and further reduction, and go back with the regular chop into the first section of the feed hopper.

The offal from the first section, which is very poor and only fit for feed, is conveyed from one side of the machine into some receptacle, while that from the second and third sections, which is rich enough for reduction to a low grade of flour, is conveyed into another from the other side.

When the capacity of a mill is sufficient for three machines, "simple" machines are used in place of "combination," the different machines taking the place of the different sections in the "combination," and operating in substantially the same way.

[Since reading the above paper the writer understands from the manufacturers of the machine that they have discovered the efficiency of the machine as at first constructed, and as above described, can be greatly improved by the use of—in place of hard rubber in cylindrical shape for the attractive force—flat plates to move backward and forward. This change will allow a greatly increased electrified surface presented to the middlings over the same sieve surface—an increase of three or four times, which must necessarily increase the capacity of the machine and the thoroughness of its work, and very considerably decrease the cost of construction.

The cylinder apparatus has been in operation in the Atlantic Mills at Brooklyn for over a year, and the proprietors, F. E. Smith & Co., say that it saves them ten to twenty cents on every barrel of flour.]

Porous Bricks.—The association of proprietors of steam engines in the north of France have made numerous experiments which show that many of the bricks that are employed in building furnaces are so porous as to allow an easy passage for the air. In consequence of these experiments they advise that no bricks should be employed for the purpose which are not very compact and refractory, and that they should be either glazed upon the outside or covered with an impenetrable varnish.—*Chron. Industr.* C.

ON THE CONSTANTS IN GORDON'S FORMULA FOR THE STRENGTH OF COLUMNS.

By MANSFIELD MERRIMAN,
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Gordon's formula for the discussion of the strength of columns is, in its most general form,

$$\frac{P}{A} = \frac{m}{1 + n\dfrac{l^2}{r^2}}$$

in which P denotes the breaking load, A the area of the cross section of the column, l its length, r the least radius of gyration of the cross section, and m and n are constants, whose values depend on the kind of material and arrangement of ends of the column.

In order to ascertain the signification of the constants m and n let us give a mathematical deduction of the form of the above formula.

Let a column whose length is l and cross section A be loaded with a weight P. The average unit compressive strain on the cross section is then $\frac{P}{A}$. But in consequence of the bending, or sidewise deflection, of the column the unit strain on the concave side becomes greater than $\frac{P}{A}$, and that on the convex side less. Let S represent the greatest unit compressive strain on the concave side, and F that portion of S due to the flexure. Then

$$S = \frac{P}{A} + F$$

Now, provided that the material of the column is not strained beyond its elastic limit, the value of F may be deduced from the usual equation for the flexure of beams, namely,

$$M = \frac{F\,I}{c} \quad \text{or} \quad F = \frac{M\,c}{I},$$

where I is the least moment of inertia of the cross section, c the distance from the concave side to the neutral axis of the flexural strains, and M the bending moment of the external forces with reference to the neutral axis. We have then

$$S = \frac{P}{A} + \frac{Mc}{I}$$

But in the case of the column $M = P\Delta$, where Δ is the maximum sidewise deflection, and $I = Ar^2$. Hence

$$S = \frac{P}{A}\left(1 + \frac{\Delta c}{r^2}\right)$$

which may be written

$$\frac{P}{A} = \frac{S}{1 + \frac{\Delta c}{r^2}}$$

In order to determine Δ we must turn again to the theory of the elastic flexure of beams, where we find for a beam supported at both ends and loaded in the middle

$$\Delta = \frac{Fl^2}{12\,Ec}$$

where E is the modulus of elasticity of the material. From this we have

$$\Delta c = \frac{F\,l^2}{12\,E} = \left(S - \frac{P}{A}\right)\frac{l^2}{12\,E}$$

and by substitution in the above value $\frac{P}{A}$ we find

$$\frac{P}{A} = \frac{S}{1 + \left(S - \frac{P}{A}\right)\frac{l^2}{12\,E\,r^2}} \qquad (a)$$

which applies to a column with ends arranged similar to those of a beam supported, namely, to a column with round or hinged ends.

In the same way we find for a column with fixed ends a similar expression, having 24 in the place of 12; and for a column with one end round and the other end fixed also a similar expression, having 17 in the place of 12.

It thus appears that the constant m in the formula

$$\frac{P}{A} = \frac{m}{1 + n\frac{l^2}{r^2}}$$

signifies the greatest unit compressive strain S due to the stress P, provided the elastic limit be not exceeded. And also, under the same restriction, that the constant n has the following values:

$$n = \frac{S - \frac{P}{A}}{12\ E} \text{ for round ended columns,}$$

$$n = \frac{S - \frac{P}{A}}{17\ E} \text{ for one end round and the other fixed,}$$

$$n = \frac{S - \frac{P}{A}}{24\ E} \text{ for flat or fixed ended columns.}$$

It hence is evident that n is not a constant, as it varies with $\frac{P}{A}$, and for columns strained to the same point S its value is greater the greater the length of the column, since we know from experiment that $\frac{P}{A}$ decreases when the length of the column increases.

There are no means of determining what the values of m and n might be when the material is strained beyond the elastic limit, for the laws governing the resistance of materials in that condition are as yet only imperfectly understood. Usually Gordon's formula is applied to the rupture of columns, and m taken to be the ultimate unit compressive strength of the material; yet it is well known that for wrought iron, for instance, the usual value, $m = 36{,}000$ pounds per square inch, is much less than the ultimate strength. And it is also known that the formula entirely fails to represent the results of experiments unless columns shorter in length than about fifteen diameters are excluded, although its deduction contains no such restriction in regard to length. It hence appears that Gordon's formula should be regarded as of an empirical nature, and not be considered as representing at all the actual laws connected with the rupture of columns.

Formula (a) deduced above appears in an unsatisfactory condition owing to the presence of $\frac{P}{A}$ in both members of the equation. Solving it for $\frac{P}{A}$ we observe, with surprise, that

$$\frac{P}{A} = 12\ E\ \frac{r^2}{l^2}$$

which is identical, except in the constant (which should be π^2), with Euler's formula for the elastic resistance of round ended columns.

CHRONOLOGICAL TABLE OF AMERICAN PATENTS.*

By E. HILTEBRAND,
Librarian of the Franklin Institute.

In the Patent Office reports published prior to 1843 the names of patentees only appear with the subjects and dates of patents granted. In 1843 the publication of claims began with Wilbar's Patent, numbered 2901. There were granted, therefore, 2900 patents of which the claims or other descriptive matter have never been printed for public use by the Patent Office.

In the year 1826, when the *Franklin Journal* (now THE JOURNAL OF THE FRANKLIN INSTITUTE) was established, there was printed therein a list of the patents granted between December 12, 1825, and December 31, 1827, but without the claims. In the year 1828, however, it was decided to publish the claims, with remarks by the editor, or other descriptive matter of the patents. This was continued until March, 1836, from which time, until October of the same year, the claims were omitted and the names of patentees and subjects only, printed, as was done prior to 1827.

In 1837 another change was made, and the printing of the claims was resumed, and continued until the end of the year 1859. (From 1860 to date the claims and specifications are numerically arranged in the official reports, and are accompanied by alphabetical indexes of patentees and subjects.)

These lists, which sometimes presented the patents of one month, or those of a shorter or longer period, were published in an irregular manner, as will be seen by comparing the column showing the date of the granting of a patent with that showing the date of publication of the volumes of the JOURNAL. The following table is therefore intended to aid (provided the date of the granting of a patent is known),†

1st. In finding at once those claims of patents granted prior to 1843 which were published in this journal.

2d. In finding the claims of any patent granted between 1843 and 1859, inclusive, much more readily than from the Patent Office publications bearing those dates.

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*June, 1828, October, 1833, and November and December, 1836, were not published.

† Should the title of a patent, or name of patentee, be known, and *not* the date of the granting of the patent, it is necessary to refer to the "Subject Matter Index of Patents, 1790 to 1873," Washington, 1874, in which the date will be found; then refer to corresponding date in the table, where, on the same line, is given the number of the volume containing the description.

TABLE *of American Patents published in* THE JOURNAL OF THE FRANKLIN INSTITUTE *between the Years 1826 and 1860.*

Year	and Months in which Patents were Granted.	Series.	Volume.	Whole No. of Vol.	Date of Pub. of. Vol.
1825	December 12 to December 31	1	1	1	1826
1826	January 1 to April 26	1	1	1	1826
1826	April 12 to August 30	1	2	2	1826
1826	August 31 to September 14	1	3	3	1827
1826	September to October	1	4	4	1827
1826	November 4 to 16	1	3	3	1827
1826	November 20 to December 30	1	4	4	1827
1827	January 3 to February 15	1	4	4	1827
1827	February 15 to April 10	1	4	4	1827
1827	February 15 to December 31	2	1	5	1828
1828	January and February	2	1	5	1828
1828	March to May	2	2	6	1828
1828	July to October	2	2	6	1828
1828	October to December	2	3	7	1829
1829	January to March	2	3	7	1829
1829	April to September	2	4	8	1829
1829	October to December	2	5	9	1830
1830	January to March	2	5	9	1830
1830	April to October	2	6	10	1830
1830	October to December	2	7	11	1831
1831	January and February	2	7	11	1831
1831	March to June	2	8	12	1831
1831	July to December	2	9	13	1832
1832	January to May	2	10	14	1832
1832	June to December	2	11	15	1833
1832	Supplemental list to July	2	15	19	1835
1833	January to June	2	12	16	1833
1833	July to September	2	13	17	1834
1833	Supplemental list to August	2	15	19	1835
1833	November and December	2	13	17	1834
1833	December	2	14	18	1834
1834	January to May	2	14	18	1834
1834	June to November	2	15	19	1835
1834	December	2	16	20	1835
1835	January to May	2	16	20	1835
1835	June to November	2	17	21	1836
1835	December	2	18	22	1836
1836	January to March	2	18	22	1836
1836	April to October	2	18	22	1836
1837	January to March	2	20	24	1837
1837	April to August	2	21	25	1838
1837	September to November	2	22	26	1838
1837	November	3	8	38	1844
1837	December	2	22	26	1838
1838	January and February	2	22	26	1838
1838	March to June	2	23	27	1839
1838	July to December	2	24	28	1839
1839	January to May	2	25	29	1840
1839	June to October	2	26	30	1840
1839	November and December	3	1	31	1841
1840	January to April	3	1	31	1841
1840	May to October	3	2	32	1841
1840	November and December	3	3	33	1842
1841	January to April	3	3	33	1842
1841	May to August	3	4	34	1842
1841	September	3	8	38	1844
1841	October and November	3	9	39	1845

Year	and Months in which Patents were Granted.	Series.	Volume.	Whole No. of Vol.	Date of Pub. of Vol.
1841	December	3	10	40	1845
1842	January	3	11	40	1845
1842	January and February	3	11	41	1846
1842	March to April	3	12	42	1846
1842	April	3	13	43	1847
1842	May	3	14	44	1847
1842	May and June	3	15	45	1848
1842	June	3	8	38	1844
1842	July to December	3	16	46	1848
1843	January to June	3	17	47	1849
1843	July to September	3	18	48	1849
1843	October	3	8	38	1844
1843	October to December	3	18	48	1849
1844	January to April	3	8	38	1844
1844	May to October	3	9	39	1845
1844	November and December	3	10	40	1845
1845	January and February	3	10	40	1845
1845	March to July	3	11	41	1846
1845	August to November	3	12	42	1846
1845	December	3	13	43	1847
1846	January to May	3	13	43	1847
1846	June to August	3	14	44	1847
1846	September to December	3	15	45	1848
1847	January to March	3	15	45	1848
1847	April to September	3	16	46	1848
1847	October to December	3	17	47	1849
1848	January to August	3	17	47	1849
1848	September to December	3	18	48	1849
1849	January to April	3	18	48	1849
1849	May to December	3	19	49	1850
1850	January and February	3	19	49	1850
1850	March to November	3	20	50	1851
1850	November and December	3	21	51	1851
1851	January to May	3	21	51	1851
1851	May to November	3	22	52	1851
1851	November and December	3	23	53	1852
1852	January to April	3	23	53	1852
1852	May to November	3	24	54	1852
1852	November to December	3	25	55	1853
1853	January to May	3	25	55	1853
1853	May to November	3	26	56	1853
1853	November to December	3	27	57	1854
1854	January to April	3	27	57	1854
1854	May to October	3	28	58	1854
1854	October to December	3	29	59	1855
1855	January to April	3	29	59	1855
1855	May to November	3	30	60	1855
1855	November and December	3	31	61	1856
1856	January to April	3	31	61	1856
1856	April to October	3	32	62	1856
1856	November and December	3	33	63	1857
1857	January to April	3	33	63	1857
1857	April to September	3	34	64	1857
1857	October to December	3	35	65	1858
1858	January to March	3	35	65	1858
1858	March to September	3	36	66	1858
1858	October to December	3	37	67	1859
1859	January to April	3	37	67	1859
1859	April to September	3	38	68	1859
1859	October to December	3	39	69	1860

THE WESTINGHOUSE CONTINUOUS BRAKE.

It is about ten years since Mr. George Westinghouse first came over to England with the object of inducing railway companies in this country and on the Continent to adopt his system of continuous air brake, which had at that time found a large and very useful application on the railways of the United States. At that time continuous brakes were only exceptionally used on English railways, and not at all on the Continent. Here the necessity for them was realized, but not so fully as a few years later, when the increase in the number of trains and the acceleration of speeds rendered some efficient means of controlling trains absolutely necessary. The Board of Trade took action in the matter by a series of exhaustive trials, and having satisfied themselves as to the requirements of an efficient brake, and also as to what could be done within practical working limits, laid down a series of conditions sufficiently stringent, but capable of being fulfilled by one system—the Westinghouse automatic. This was a very considerable advance over the original Westinghouse continuous air brake, which was, however, until the introduction of the improved system, the most efficient that had been introduced. These trials took place in June, 1875, and were only one series of a large number carried out before and since both in this country and on the Continent, and which proved conclusively the superiority of the Westinghouse brake over all the other systems with which it came into competition. In spite of this undoubted superiority, the adoption of the automatic air brake proceeded but very slowly on English railways, owing to causes with which we need not trouble ourselves now. But however slow this progress, it has been at all events steady, and during the last two years has advanced with more rapid steps, while on the Continent the adoption of the Westinghouse automatic brake may be said, as regards France and Belgium, to be universal. An examination of the results obtained will show, indeed, that Mr. Westinghouse has established his system in Europe on as strong a basis as in the United States. Up to the 25th of November the number of automatic brakes in use or ordered for immediate application were as given in the following table.

Country.	Engines.	Carriages.
England,	1087	7719
France,	1416	7193
Belgium,	359	1728
Germany,	63	105
Austria,	4	32
Russia,	64	51
Holland,	59	208
Italy,	11	35
Sweden,	1	6
India,	6	60
New South Wales,	66	124
South Australia,	27	18
Queensland,	1	11
United States,	3435	12,270
	6599	29,560

In England the system is in use on 14 different railways, the chief of which are the North-Eastern, with 328 engines and 2343 carriages; the London, Brighton and South Coast Railway, with 256 engines and 2116 carriages, and the Great Eastern with 136 engines and 1064 carriages. The North British, the Caledonian and the Glasgow and South-Western also have their stock fitted with the brake. In France the system may be said to be universally adopted, since it is the standard brake on the Western, Ceinture, the Paris, Lyons and Mediterranean; the Orleans and Midi have accepted it. The State railways of France have not yet definitely decided, and the Northern, which for some time has employed the vacuum brake, has still that system in use. There is little doubt, however, that with a uniform system throughout the other railways, the Northern will soon decide on making a change. In Belgium, on the whole *réseau* of State railways, the Westinghouse automatic brake is used, it having been very early adopted by the government, which has every reason to be satisfied with the wisdom of their selection. In the United States it is of course recognized as the standard system, no less than 190 railway companies employing it. As regards the non-automatic or early continuous brake, its use continues to a large extent in America, there being in service on United States lines 2579 engines and 11,389 cars fitted, while in England and the colonies there are 58 engines and 399 carriages running with the

brakes. Thus the total of railway stock to which Westinghouse brakes have been applied and are to-day in use amount to no less than 9236 engines and 41,349 carriages. These figures are more conclusive than any argument could be of the acknowledged efficiency of the system. Despite the hesitation, indifference and in some cases obstructiveness of locomotive superintendents in this country, the example set by Belgium and France (in both of which countries the automatic brake was promptly decided upon) will doubtless be followed here as soon as public and official pressure enforces general action. The Westinghouse Brake Company, Limited, employs more than 500 men manufacturing automatic brake apparatus in their various establishments in Europe, the present capacity for turning out work being equal to 1200 carriages and a proportionate number of locomotives per month.—*Engineering.*

Action of Cold upon the Voltaic Arc.—D. Tommasi publishes the following conclusions from his experiments: When the voltaic arc springs between two metallic rheophores, each formed by a U-shaped tube, traversed by a rapid current of cold water, and placed horizontally near to each other, the following facts are observed: 1. The illuminating power of the arc is greatly weakened, being reduced to a simple luminous point even when a very intense electric current is employed. 2. The arc, if it can be called so, is very unstable; the least breath extinguishes it, and it cannot even light a match without being extinguished itself. 3. If a piece of paper is placed above the arc, and very near it, a black point is formed, which spreads and finally breaks, but the paper does not kindle. 4. The arc consists of a luminous globule, moving up and down between the two rheophores; the form of the globule as well as its extreme mobility reminds one of a drop of liquid in the spheroidal state. 5. If the south pole of a magnetized bar approaches the arc, it is attracted by the magnet and extinguished. The same fact is observed, but in the opposite direction, upon the approach of the north pole. 6. The quantity of ozone seems to be greater than when the arc is not cooled. In spite of the cooling of the rheophores the flame is slightly green, which shows that a portion of the copper is burnt. Tommasi proposes to experiment with platinum rheophores, with alcohol cooled to —30° (—22° F.).—*Compt. Rendus.* C.

Diffusion of Electric Light.—M. Clemandot was induced, by observing the diffusion of the solar light by clouds, to experiment with mineral wool, or spun slag, in connection with the electric arc, and found that it seemed to absorb the light like a sponge, so as to make from 75 to 80 per cent. available for illumination while the ordinary processes utilize only from 45 to 50 per cent. at the most.—*La Nature.* C.

A French Experiment in Ship-building.—During the French blockade by the English fleet Napoleon established a maritime arsenal in Venice, where a number of vessels were built. One day a brig, upon which great expectations had been founded, left the port without having time for trial; but it sailed so slowly that it was captured by an English ship before it reached the open sea. The French crew was replaced by an English crew, which was soon disappointed at finding that it was almost impossible to move the brig. Upon examination it was suspected that the principal mast had been badly stepped. Carpenters were called, who gave the mast a greater inclination, and after spreading the sails anew the brig was found to be a faster sailer than any other in the English fleet.—*Les Mondes.* C.

Speech of Deaf Mutes.—F. Hémant having observed that deaf mutes, when taught to talk, speak with a peculiar local intonation, attributed the fact to organic conformation similar to that of their parents, and regarded it as a new example of physical resemblances transmitted by heredity. Emil Blanchard objects to this conclusion. He says that the voice of those who are deaf from birth is hoarse, metallic, guttural, without modulation or inflection, and free from the ordinary accents of the human voice. Upon learning to speak, the master shows how it is necessary to place the lips, to open the mouth, to close or separate the teeth, to swell the cheeks, in order to produce the various sounds. Thus it is easy to understand that the pupil may copy the accent or intonations of the master. The question whether the presence or absence of certain articulations in the idiom of any people coincides with peculiarities of the phonetic apparatus is still undecided. A final answer cannot be given until several children of races speaking very different and peculiar idioms shall have been taken from their parents in infancy and accustomed to speak some European language. —*Comptes Rendus.* C.

Hiving Bees by Electricity.—Electricity has been successfully applied in capturing swarms of bees which have been collected on walls or trees. If a gentle current is passed through the swarm they become benumbed so that they can be handled without danger.—*Der Techniker.* C.

The Severn Tunnel.—The total length of the Severn tunnel is 3701 metres (2·305 miles). The longest gallery was begun in January, 1875; in October, 1879, the work was interrupted by an invasion of fresh water, when the galleries were within 39 metres (42·65 yards) of meeting. After pumping out the water the work was resumed in August last, and completed in a very satisfactory manner. The breadth of the galleries was only 3 metres (9·843 feet); one of them had an inclination of one foot per 100, which increased the difficulty of surveying; nevertheless, the Monmouthshire section, of 3081 metres, and the Gloucester section, of 620, met without any perceptible deviation. The duration of the work was four years and ten months, including all delays except that of 18 months which was caused by the irruption of the water. The time was lengthened by the narrowness of the galleries and the nature of the rock, which was found to be very hard for more than one-half of the length of the tunnel.—*Ann. des Ponts et Chaussées.* C.

Transformation of Sound into Light.—In 1879, a year before the invention of the photophone, M. Trève made an experiment which is the reverse of the photophone. A Fizeau condenser, consisting of sheets of paper alternating with tin foil, was rolled and placed in a Geissler tube, which was connected with an air pump. The current of a Ruhmkorff coil was passed into the tube, and a telephone was placed in the induced current. While the current was passing, the roaring of the electricity in the condenser could be heard in the telephone. If the pressure of the air in the tube was gradually diminished by the air pump, the roaring subsided; when a vacuum of two or three millimetres (·079 to ·118 in.) was reached the noise ceased altogether, and light began to play against the leaves of the condenser. It was not the well-known vague and diffuse light of the Geissler tubes, but a special, condensed, pearly radiance. It was necessary that the electricity should be manifested in some way, and as it could not be transformed into sound, on account of the rarefaction of the air, it was changed into light.—*Les Mondes.* C.

Chili Saltpetre.—Nitrate of soda is found in great abundance in the desert of Atacama. Under a bed of soil, varying in thickness from 10 to 50 centimetres (3·937 to 19·685 in.), there is a compact layer of gypsum, under which the salpetre is found in irregular beds, with a thickness sometimes reaching to two metres (6·562 ft.). It is often mixed with sulphate of soda. It comes from the decomposition of the feldspathic rocks, and, as these rocks form the central part of the desert, the supply seems to be almost inexhaustible.—*Les Mondes.* C.

Storms and Sun Spots.—M. L. Cruls, in collecting materials for the study of the meteorology of Rio de Janeiro, was struck with the remarkable variation in the annual number of storms. Knowing the importance of the electromagnetic action of the sun in many of the physical phenomena of the globe, and the evident relation that exists between the periodicity of some of these phenomena and that of the sun spots, he instituted a comparison which showed a remarkable similarity between the curves representing the annual number of storms and the relative number of sun spots in Brazil. He found a similar accordance, though less striking, in the records of the Toronto Observatory. Faye regards this communication as a very striking confirmation of the views which he has been advocating for many years.—*Comptes Rendus.* C.

Manageable Anæsthetics.—Paul Bert has been experimenting upon the anæsthesia of animals with mixtures of variable proportions. He calls the interval between the anæsthetic dose and the mortal dose the manageable zone, and his experiments seem to indicate that in all cases the mortal dose is just double the anæsthetic dose. If the mixture represents about the middle of the manageable zone, an animal is quieted very rapidly, and remains tranquil during the whole time of the experiment, even if it lasts for a period of two hours. A few drops of the liquid, if they are breathed without a proper mixture of air, may suffice to carry the patient from the manageable to the mortal zone. Most anæsthetics seem to act, not by the quantity, but by the proportion which they hold to the air that is breathed. It seems probable that these proportions may be so exactly ascertained that all anæsthetics may be used with perfect impunity.—*Comptes Rendus.* C.

Influence of Telegraph Wires upon Birds.—In the neighborhood of the pine forests of Norway the telegraph posts which have been freshly impregnated with sulphate of copper are often found to be entirely perforated by the woodpeckers. The resonance, which is produced by the vibrations of the wires, leads the bird to suppose that there are worms and insects in the interior, and holes are consequently made which are sometimes as large as a man's arm. They are generally found near the insulators.—*La Nature.* C.

Gigantic Algæ.—The *Madras Mail* contains an account, by Captain Taylor, of an enormous monster which he saw while at anchor in Table Bay. It was more than 100 feet in length, and appeared to glide over the water with an undulatory motion, like a serpent. Its head seemed to be surmounted by something like a long mane, and the observers who had the sharpest sight affirmed with fear that they could distinguish its features and even its eyes. He collected the crew and directed a brisk fire of musketry upon the monster, at a disance of about 500 yards. When it seemed to have been seriously injured, and its movements were a little quieted, boats were sent out to examine it more closely and to finish its destruction. It was then found that they had been fighting a magnificent specimen of the *giant herb of the sea*, of which the undulatory motions were caused by the agitation of the waves near the shore.—*Les Mondes.* C.

Bears, Wolves and Telegraphs.—The director of the Norwegian telegraphs says that the bears are often attracted by the humming of the wires, which sound they suppose to come from a swarm of bees. On reaching the posts and finding no hive they think it is hidden under the heap of stones at the foot of the post, and scatter them in all directions. When the first telegraphic lines were established in Norway a member of the Stortheig stated that, although his district had no direct interest in the proposed line, he would vote for the appropriation, because, in his opinion, the wires would drive the wolves from the whole region. It had already been noticed that wolves, however hungry they might be, would never enter yards which were closed by simple cords stretched between posts. Whether for this reason or for some other, it is a fact that since the line was established, a period of more than 20 years, the wolves have disappeared. —*L'Electricien.* C.

Franklin Institute.

Hall of the Institute, Dec. 21st, 1881.

The stated meeting was called to order at 8 o'clock P.M., the President, Mr. William P. Tatham, in the chair.

There were present 139 members and 28 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers and announced that at the last meeting of the Board 26 persons were elected members of the Institute.

The President announced that nominations for officers to serve the ensuing year were, in accordance with Article XIV, Section 7 of the By-laws, the privileged business of the meeting; and, after the reading of the names of those whose terms would expire, he asked for nominations.

The following members were placed in nomination:

For President, William P. Tatham.

" *Vice Presidents* (to serve for three years, and for the unexpired term of Mr. Cartwright), J. E. Mitchell and Frederick Graff.

For Secretary, Dr. Isaac Norris and Dr. W. H. Wahl.

" *Treasurer*, Frederick Fraley.

" *Managers* (to serve for three years), William Sellers, J. Vaughan Merrick, Hector Orr, Cyrus Chambers, Jr., Prof. William D. Marks, W. V. McKean, Henry R. Heyl, Dr. Robert E. Rogers.

For Auditor (to serve for three years), W. B. Cooper.

" *Trustee in Pennsylvania Museum and School of Industrial Art*, Dr. Isaac Norris.

Prof. Rogers, chairman of the Committee on the "Precautions to be taken to obviate the dangers that may arise from Systems of Electric Lighting," presented the report, which was published in full in the December number of the Journal.

Prof. Rogers suggested that, as the paper had been published, the reading of it could be dispensed with; and Mr. Mitchell, endorsing it as an admirable one, moved that it be adopted.

Mr. Shaw thought that some members, although they had received copies of the report, had had no opportunity to read it, and said that they should not be called upon to adopt it without knowing what it

contained. He had not read it, and thought it would be better to postpone its consideration until the next meeting.

Objection was made to postponement, and the President deciding that the reading had been called for, all motions on the subject were withdrawn and the Secretary read the report from the printed copy.

Prof. Rogers said that the committee had given a great deal of solicitous thought to the subject and worked up all the problems presented to them. He wanted to emphasize some of the recommendations of the report. One of these was the necessity of making good connections, not liable to be broken or impaired by jarring, especially where short pieces of wire were used. Another important matter was to have the wire sufficiently thick to carry the current without heating. He emphasized these points by telling of an accident which occurred to one of the electric lights on Chestnut street, and which he witnessed. The light having been extinguished from some cause, about a yard of copper wire was heated to a red heat by the current, and this ignited the combustible insulating material by which the main conductor was covered. The copper was also melted, and a voltaic arc formed in the copper vapor. It was easy to see how such an accident in a building might create a fire, and this demonstrated the necessity of observing the precautions recommended by the committee.

The report was then adopted by a vote which appeared to be unanimous; and, on motion of Mr. Mitchell, the thanks of the Institute were tendered to the committee for their valuable services.

Mr. Hector Orr then addressed the Institute briefly on the progress made and being made in the silk and flax industries of the country. He recalled the aid given to these industries by the Franklin Institute, especially in the development of machinery for the manufacture of textile fabrics, declaring that Philadelphia had done more in the way of improving such machinery than all the rest of the world "since Egypt first wrapped her mummies in linen made of flax." He said, in conclusion, that he thought the Institute ought to be promptly given the $200,000 required for its proposed new building, this being "only one-fourth of one per cent. of the sum represented by the annual trade of these two staples, the manufacture of which has been fostered by the Institute."

Mr. William Barnet LeVan read a paper on rapid transit, in which he advanced the idea that railroads would eventually be used only for carrying freight, and that passengers would be conveyed from one

place to another by the pneumatic system, at higher rates of speed than are now attainable on steam railroads. He described the general features of a pneumatic road which, he thought, should be built on Market street, instead of the proposed elevated railroad, and said that its first cost, as well as its running expenses, would be less than that of a steam railroad. His plan contemplated the building of two ten-feet tunnels, one for up and the other for down trains, finished smooth on the inside and made air-tight. The cars would be of iron, cylindrical in shape and with seats for passengers running lengthwise. They would be propelled by atmospheric pressure, fans driven by stationary steam engines at various points on the line exhausting the air in front of them. He described how arrangements could be made to stop the cars at stations, or to allow them to pass as express trains, and how the movements of trains could be indicated in the station and engine blower rooms. Pneumatic tubes are now used for the transmission of messages, packages, etc., in many places, and in London there is a tunnel, 4½ feet in diameter, used for the transmission of the mails a distance of two miles. Several people have made the trip in the mail cars, the first to do so being the Duke of Buckingham and some friends, as long ago as October 10, 1865. They were transported through the tube at the rate of 12 miles an hour. Mr. LeVan expressed the opinion that the pneumatic system would do away with most of the existing objections to railroads on which steam is used as the motive power, and looked forward to the day when such a road would connect the cities of New York and Philadelphia.

Mr. Shaw inquired whether any allowance had been made for the frictional resistance of the air column in a long tube such as that between New York and Philadelphia would have to be.

Mr. Le Van said that he proposed to overcome whatever resistance there might be by having a number of engines and stations. In reply to other questions Mr. Le Van said he proposed to use rubber or leather for packing.

Prof. Rogers inquired whether he had made any arrangements to preserve the lives of the passengers traveling at the proposed speed and under the compression required to maintain it.

Mr. Nystrom said that the difference in pressure would not be greater than that between the pressure at the sea level and on a high mountain.

In reply to further inquiries Mr. Le Van said that the proposed size

of the wheels was 48 inches, and that the estimate of the cost of laying the tube between Philadelphia and New York, sometimes under ground and sometimes above ground, was about $60,000,000, and that this would be less than the cost of an elevated road.

Wendell's Car Journal Box was shown in various forms, and was described by Mr. C. Henry Roney, C.E. In cars and locomotive engines the weight of the vehicle rests upon the axle, and the lubricator of the latter, to be effective, should be on the top of the journal. In the ordinary box, cotton waste, saturated with oil, is employed as a stuffing, so that the oil may be carried up by capillary attraction to the journal. It answers the purpose only imperfectly, however, sometimes collecting dust on its surface and sometimes dropping away and leaving the journal without lubrication and exposed to the dangers of heating. In the box invented by Mr. Wendell no stuffing is employed, but in place thereof there is a small force pump, with ball valves, operated by the vertical motion of the car on its truck. The oil is thus automatically pumped from the bottom of the box to the top of the bearings, through which are openings carrying it direct to the top of the journal, whence it falls to the bottom of the box. A leather or cork shoulder packing is used to prevent the escape of oil or the admission of dust. The boxes are made in three forms: one for steam railway cars, one for street cars, and one as an attachment to be put in place of the door or lid on boxes now in use. The inventor claims a very great saving in brasses and lubricants by the use of this box.

Mr. Roney also exhibited photographs of Thompson's Patent Wet Pulverizer, manufactured by S. P. M. Tasker, for which also the chief claim is economy. It is claimed that in stamps one shoe weighing about 300 pounds will crush forty tons of quartz rock before being worn out, while this pulverizer, with a ball weighing 180 pounds (which is the crushing part) will crush three hundred tons of the same rock fine enough to pass through a 60-mesh screen. The first cost is also said to be less than for stamps in ordinary use.

Mr. Washington Jones mentioned some stamps now in use which pulverize 100 tons of quartz rock per stamp in twenty-four hours, and said that the wear of shoes amounted to about a quarter of a pound of iron per ton of crushed stone.

Mr. Roney said that this was about the same as the wear claimed for Thompson's pulverizer.

The Secretary's report on new inventions, of which models or sam-

ples were exhibited, included the following: Burgess' Air Compressor, which is adapted for physicians' use, for spraying the throat and nasal passages, for atomizing in surgery and for disinfecting rooms, hospitals, etc. The air pump is operated by foot power.

The Zimmerman's Students' Lamp is an elaborate arrangement for lighting the ordinary oil lamp without the use of matches, and for extinguishing without the risk entailed in blowing down the chimney. Opposite the lamp on the standard is an electrical battery and a jar in which hydrogen gas is generated. The battery is used to heat a platinum wire which in turn lights the gas, and that, being directed against the wick of the lamp, lights it. The extinguisher is a rubber ball connected with the central draft tube of the lamp. By compressing the ball a current of cold air is directed against the flame from below and extinguishes it.

Pfautz's Elevating Tower was exhibited in model. It is an extensible apparatus, designed to furnish a platform which may be raised and lowered and used as a fire-escape. The frame or truck is mounted on wheels, so that it may be easily shifted from one place to another.

Kurtz's Fire Ladder, an extensible ladder, mounted on a wheeled truck, was also shown in model.

William R. Fowler's Cloth Cutting Machine was exhibited by the American Cloth Cutting Machine Company. The cutting bed is studded with short vertical wires, on which the cloth rests. The cutters, driven by steam power, are mounted on the end of a flexible arm. They cut upward against a pressure plate on top of the several layers of cloth, and pass freely around the wires on the cutting bed without injury to the knives.

Dr. W. G. A. Bonwill's Dental Engine, also adapted to use in surgery, was exhibited and explained by the inventor. It is run by foot or hand power, circular saws, drills and other cutting instruments being affixed to the end of a flexible arm and revolved at a very high rate of speed. The bones of the body can be drilled or cut in any desired manner with great speed and exactness by the use of this engine.

Prof. Rogers said that Dr. Bonwill's engine deserved recognition as a means of alleviating pain by expediting the work of surgery.

A resolution inviting publishers to send copies of new books to the Institute for notice in the JOURNAL was referred to the Committee on Library.

Mr. Mitchell reported that the Committee on Exhibitions, after examining Industrial Hall, and considering the question of holding an exhibition of small apparatus there during the present winter, had come to the conclusion that it was inexpedient to hold such an exhibition at this time.

On motion, the Institute adjourned.

ISAAC NORRIS, M.D., *Secretary.*

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ON THE BEHAVIOR OF STEAM IN THE STEAM ENGINE CYLINDER, AND ON CURVES OF EFFICIENCY.

A paper read before the New York Academy of Sciences, Feb. 13th, 1882.

By ROBERT H. THURSTON, Fellow of the Academy.

In an earlier paper* the writer endeavored to show what are the conditions determining the ratio of expansion in steam engines working at maximum efficiency, and how those conditions vary in different types of engine, and also how essentially different is the actual working engine, in all that affects that ratio, from the hypothetical case usually taken, in which the steam is assumed to expand adiabatically in a non-conducting steam cylinder. It was finally shown what were the best values of this ratio for several standard types and representative cases, as determined by the writer by direct observation and by the study of experimentally obtained results, the precise figures given being obtained by rules of simple form so deduced.

It was shown that first friction and then—often to a vastly greater extent—cylinder condensation, due to expansion of a heated fluid in a working cylinder made of a material of high conducting power, mod-

* On the Ratio of Expansion at Maximum Efficiency in Steam Engines; Trans. Am. Soc. Mech. Engrs., 1881; JOUR. FRANKLIN INSTITUTE, May, 1881.

ify the methods of expansion and of expenditure of heat so greatly that the ratio of expansion for maximum efficiency, in unjacketed engines, rarely exceeds $\frac{1}{2}\sqrt{P}$, where P is the gauge pressure in pounds per square inch, although its value would otherwise be, often, several times greater. It was also shown that these modifying conditions very differently affect different kinds of steam engine and different engines and also individual engines, at various pressures and piston speeds.

It is now proposed to show more fully what is the behavior of steam in the steam engine cylinder and to exhibit the form taken by the expansion line; to give values of mean pressures obtained under various conditions and, finally, to show the method devised by the author for laying down curves of efficiency, and to show what conclusions follow from their study.

It has become plainly evident that in no case, in steam engines as to-day constructed, can the expansion line or the curve of mean pressures be such as would be obtained in a non-conducting cylinder. Steam must always be more or less condensed at the begining, and must always carry away heat by its re-evaporization at the end of the stroke. The steam jacket checks the first operation, but accelerates the last, and, with wet steam, may scarcely decrease the evil that it is designed to prevent.

It is now equally evident that "isothermal" expansion is not likely to be met with in the steam engine, although the hyperbolic expansion line is often approximately followed. This, however, with steam and other vapors, is very different from isothermal expansion; the latter is physically impossible with wet steam, and the isothermal expansion of steam, initially dry, but saturated, would leave the vapor superheated, although at initial temperature when exhausted.

To produce this last condition heat must be furnished by the steam jacket sufficient not only to do the work of expansion, as measured by the indicator, but also a large additional quantity which is demanded to do the "internal work" of overcoming molecular attractions, *i. e.*, to supply the "latent heat of expansion" at constant temperature.

On the other hand, hyperbolic expansion of dry steam would leave the fluid superheated, also, but not at the initial temperature; while steam containing about its own weight of water, if expanded hyperbolically, would be exhausted, with the proportions of the mixture

unchanged, and with its temperature reduced to that due the lessened pressure.

Isothermal expansion lines of a *mixture* of steam and water are simply lines of uniform pressure, and could only be obtained in the steam engine by some system of heating the mass at just the rate necessary to evaporate the water as rapidly as steam might be required to keep up the pressure while the piston was moving forward—a state of things never met with in practice.

The expansion line is not only modified in position and in form by the conductivity of the cylinder, but, also, although far less seriously, by the quantity of water contained in the mass of fluid at the instant of closing the expansion valve.

The adiabatic curve may be closely represented by a regular curve of the hyperbolic class, $p_1 v_1^n = p v^n$, the exponent n varying with the proportions of steam and water in the mixture at the commencement of the expansion, which is assumed to take place in a nonconducting cylinder. Zeuner finds the value of n to be nearly $n = 1·035 + 0·1 x$, x being the proportion of steam present.

Table I, appended, gives the values of the ratio of mean pressure to initial pressure, $\frac{p_m}{p_1}$, for various mixtures from steam 1·00, water 0, to steam 0·50, water 0·50, assuming the formula to be practically accurate within that range.

With these are given the adiabatics for superheated steam, $n = 1·333$.

Table II gives the values of $\frac{p_m}{p_1}$ for steam expansion in a jacketed metal cylinder, in which it is kept just dry and saturated by heat from the jacketed sides and ends; the values for wet air compressed in air compressors, in which n is frequently found to be 1·2; and for peculiar cases in actual steam engines in which leakage or re-evaporation, or both, raise the terminal pressures greatly, giving $n = 0·50$, $n = 0·75$.

It is, as yet, impossible to predict which of these curves will be found in ordinary engines, and the engineer is compelled to rely entirely upon the "indicator" for information of this character; this instrument gives him a more or less exact graphical representation of the changes of pressures and volume throughout the stroke. The greatest possible variety of curves are found to occur in such cases,* but

* An indicator diagram lying before the writer gives $n = 1·001$ at the beginning of

they approach the adiabatic more nearly, as the steam is drier and, as the speed of piston is increased, rarely departing far from the common hyperbola in good engines. Perfectly dry or superheated steam in very fast running engines gives a curve most closely approaching the adiabatic curve, but the deviation is more marked as the speed of engine is decreased, and as the amount of moisture in the steam, initially, increases. The limit may be taken as $pv = p_1v_1$, on the one side, and to $pv^{\frac{1}{2}} = p_1v_1^{\frac{1}{2}}$ on the other, the latter being the rare case sometimes met with of an unjacketed engine working at a piston speed below 50 feet per minute (under 15 metres), and with a high ratio of expansion, while the former is a very usual limiting value with well-constructed jacketed engines at good speed.

These curves take the form here indicated, the exponent n becoming less than unity—instead of greater, as in all cases of adiabatic expansion, and usually of expansion in well-jacketed cylinders—in the following manner: Consider a steam cylinder unjacketed and worked at some extremely low speed of piston.

At the instant before the steam enters either end, that end is exposed to the chilling action of vapors forming on its warm surfaces at the pressure of the exhaust, while the opposite end is just releasing a charge of steam which has been expanded down to some pressure considerably below that of prime steam; the expansion of which charge and the re-evaporation of moisture present, chills the surface of the cylinder on that side of the piston also.

Now, the steam entering from the boiler meets the cooled metal surfaces of piston and cylinder head and condenses upon them until they attain boiler temperature, or until the closure of the steam valve checks this operation, and the charge then expands as the piston moves forward with its very slow motion, uncovering, gradually, surfaces which had been cooled by the exhaust on the other side of the piston. The expanding steam, meeting these cold surfaces, surrenders a part of its heat until they are brought fully up to the temperature of the steam, by flow of heat into the interior of the metal, after which time they, in turn, give up heat again to the steam, producing

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the stroke, $n = 0{\cdot}94$ at the middle and $n = 0{\cdot}89$ at the end. The compression line starts with $n = 1{\cdot}52$ and varies thus, $n = 1{\cdot}29$, $n = 0{\cdot}96$ to the end, where $n = 0{\cdot}77$, showing that the mean temperature of the surfaces in contact with steam is above that of the vapor during the first half of the period of compression, and below that of the fluid during the second half.

re-evaporation of the water present and giving a pressure exceeding that which would be due the same volume of expanding dry steam.

The total effect is evidently determined by the varying temperature of the cylinder walls, the temperature of exhaust and the dryness of the steam supplied.

As the piston moves forward, all parts of the cylinder hotter than the mean temperature of exposed surfaces, and all the water present, surrender heat which causes the production of steam and a tendency to increase the normal pressure. The colder surfaces constantly uncovered by the piston absorb heat, produce condensation of steam and tend to reduce pressure below the normal. As the one or the other of these effects predominates, the expansion line rises above or falls below that obtained by adiabatic expansion.

These effects are sometimes modified and rendered less observable by the occurrence of leakage—usually and principally through the steam valves—but where, as is frequently the case, the actual expansion line first falls below and then rises above the adiabatic or hyperbolic curve it may be probably safely assumed that leakage does not occur to any important extent.

Where the steam contains much water the expansion line in actual engines often, if leakage occurs, lies entirely above the curve of Marriotte, the value of n being less than unity. In other cases, the line may fall under the hyperbola at the beginning but rise far above it toward the end of the expansion, giving a curve more nearly parabolic in appearance and with a mean value of n less than unity. This increase of area of indicator diagram rarely, if ever, denotes any important gain of work done by re-evaporation.

The values of $\frac{p_m}{p_1}$ given in the tables are plotted on Plates I and II and from the latter a better idea can be obtained of the method of variation of mean pressure and of work done with variation of the ratio of expansion and a better notion of the relation of these several curves than can be gained by the study of the tabled quantities. A comparison of the engraved curves will be both interesting and instructive to the engineer. It will be observed that the adiabatics are often so nearly coincident with the hyperbolic curve, which is also the isothermal for gas, that the assumption of hyperbolic expansion, within usual ranges of expansion, whatever the mixture, is not likely to lead to serious error in estimating work. They, however, correspond to vastly different quantities of heat expended.

The tabulated values of mean pressures for adiabatic expansion and the curves exhibiting them to the eye are evidently entirely useless for the purposes of the engineer except in the few, possibly extremely rare, cases in which the modifying action of the metallic cylinder may be neglected. Such cases can only be met with, if met with at all, in the study of efficiently jacketed compound engines or of very fast running, unjacketed, non-condensing engines.

Experiment shows that superheating steam is not always very effective as a preventive of exhaust waste and that the ratio of expansion at maximum efficiency is practically the same, in unjacketed engines, whether steam is dry or superheated. The advantage undeniably obtained by the use of superheaters is, therefore, in such cases, evidently only due to the increased range of temperature of the working fluid and not to increased efficiency of engine as a machine simply.

The pressures given for a non-conducting cylinder are never exactly —and seldom, perhaps, even approximately—accurate for cases which are familiar to the engineer in practice.*

But although these curves of mean pressure are valueless, usually, for for direct application, the engineer will find them useful—indispensable, in fact—in the construction of probable mean pressure curves for proposed engines; and by properly applying them in the manner to be described, as devised and made use of by the writer, he may obtain very accurate and practically valuable Curves of Efficiency for any given class of engines; and he may then conveniently and satisfactorily solve all problems, arising in his practice, relating to efficiency of fluid, of engine or of capital expended.

Referring to Plate B, suppose a pound, a cylinderful, or other unit

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* Rankine, it is true, when investigating the theory of the condensing engine and comparing his results with those obtained by Wicksteed from the Harvey & West Cornish pumping engine, at Old Ford, finds a practical identity. This is, however, an accident due to errors of treatment of the case. He does not take into account a loss of heat by avoidable forms of exhaust waste which often amounts to a very large proportion of all heat expended and is rarely less than twenty per cent.; he omits jacket expenditure which is often ten per cent. more; but the values of n and p_1 taken in the calculations and which are inaccurate, as is now known, are such as just to compensate these errors of the expense account and to produce substantial accordance of calculated with experimental results.

A good Cornish engine, it should however be said, is peculiarly well adapted by its effective steam-jacketing, its singular distributi m of steam and its quick "indoor" stroke, to secure a maximum ratio of economical expansion and approximation of actual to ideal conditions.

of quantity of steam and water to be drawn from the boiler, carrying —we will assume with Grashof—10 per cent. its total weight of water, 90 per cent. being saturated steam, and to have a pressure which may be called 1·00 When separated from the boiler and carried into the cylinder it will retain the pressure 1·00 and, worked at full stroke, will do the work 1·00.

If supplied with additional heat until completely dry, the work becomes 1·11 at full stroke and, if worked at different ratios of expansion, such steam will give a series of mean pressures represented by the Curve of Efficiency, A_1, Plate III, as obtained from the expansion curves whose equation is $pv^{1\cdot135}$ = constant, provided expansion occurs in a non-conducting cylinder where no condensation can occur except such as is due to performance of work.

Expanded wet, as drawn from the boiler, the mean pressures of Curve B—from $pv^{1\cdot125}$ = constant, which is deduced by Zeuner for $x = 90$—are proportional to the work done by the mixture if worked without change of proportion other than occurs by production of work.

If, again, the same weight were drawn from the boiler at the pressure assumed and in the same proportions—steam 90, water 10—and if, on entering the cylinder, initial condensation should double the quantity of water present, the work at full stroke would be ·90 and the mixture would, at other ratios of expansion, the proportion remaining unchanged, give relative quantities of work measured by the ordinates of Curve C: $pv^{1\cdot116}$ = constant. It now contains steam 81, water 19.

Similarly, the proportion of water present being increased by initial condensation from the original amount carried out of the boiler, so as to reduce the work of unity of weight to ·80, ·70, ·60, ·50, etc., at full stroke, the curves of efficiency become as shown in Plate III, Curves D, E, F, etc., successively, down to the base-line where condensation has become complete and the work of expansion of the water may be neglected.

Such are the curves of efficiency, of work and of mean pressures to be obtained where steam is expanded in a non-conducting cylinder. They are easily deduced and easily constructed and, by reference to Zeuner's formula, the engineer can determine them with a satisfactory degree of accuracy for all cases which are likely to arise in his practice.

Now, studying the behavior of steam in a metallic cylinder, we

shall find vitally different conditions and results; but given the law of variation of composition of the mixture with change of point of cut-off, or of ratio of expansion, it is, nevertheless, not only practicable but easy to determine curves of efficiency and to deduce values of the best ratio of expansion for any given case.

Where direct experience can be resorted to, to determine the cylinder condensation, it is easy, as will be shown hereafter, to obtain *exact* results when seeking the ratio of expansion at maximum efficiency of fluid, of engine or of capital or in the solution of a rarer case which requires that the point of cut-off which gives most work for a given expenditure on the whole plant be determined.

In the actual engine, steam entering from the boiler—at the instant of starting the piston forward—consists of a mixture of steam and water, of which the proportions are determined by the character of the boiler-steam and the amount of initial condensation. As the piston moves forward, this proportion becomes independent of all external conditions at the instant of the closing of the steam valve. From this point on, the interchange of heat between the steam and the surrounding walls of the cylinder produces a continuous change of proportion until the exhaust-valve opens.

Thus, assuming steam to enter at a pressure 1·00 and to contain 10 per cent. water, its Curve of Efficiency* starts on Curve *B* and gradually shifts from curve to curve—as seen on the plate, Curves *K*, *L* and *M*—more or less rapidly, as cylinder condensation takes place to a greater or less extent, the real Curve of Efficiency usually crossing *C*, *D*, *E*, etc., and taking the general form indicated by lines *K*, *L*, *O* and *P*.

With considerable expansion and wet steam, the expansion line may again rise during any one stroke, by re-evaporation, toward the end of the stroke to such an extent as to somewhat increase the mean pressures, but this case is, apparently, not a very common one.

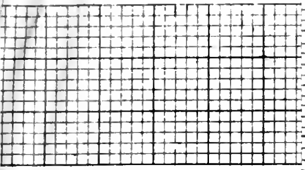
The amount of that condensation is, evidently, a function of the ratio of expansion in every engine and the writer has been accustomed to take it as varying approximately as some power of r.

Lines *K*, *L* and *M*, which are presented simply in illustration, represent, respectively, the Curves of Efficiency when the total loss by

* The Curve of Efficiency and of Mean Pressures must not be confounded with the Expansion Line representing the varying relations of pressure and volume during the stroke.

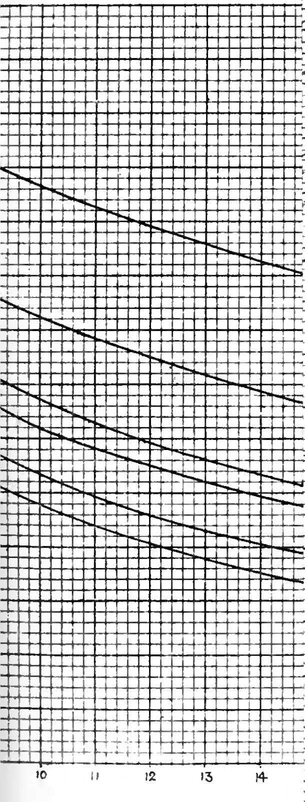
...IE STEAM ENG...

PLATE III



...RVES OF MEAN ...

...R. H. THURSTON, DES.
Nov., 1881.



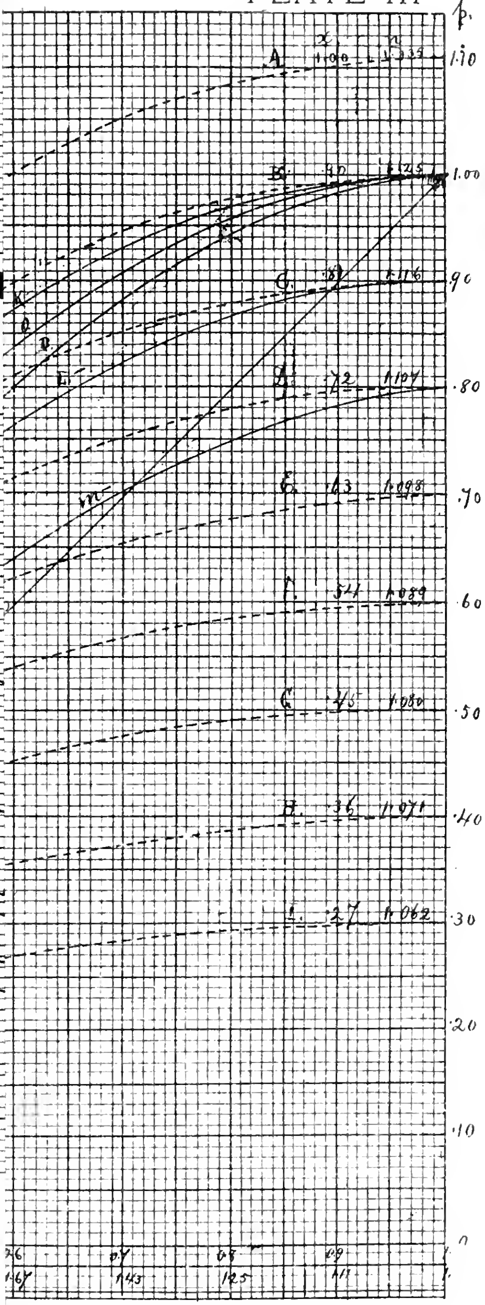


PLATE I

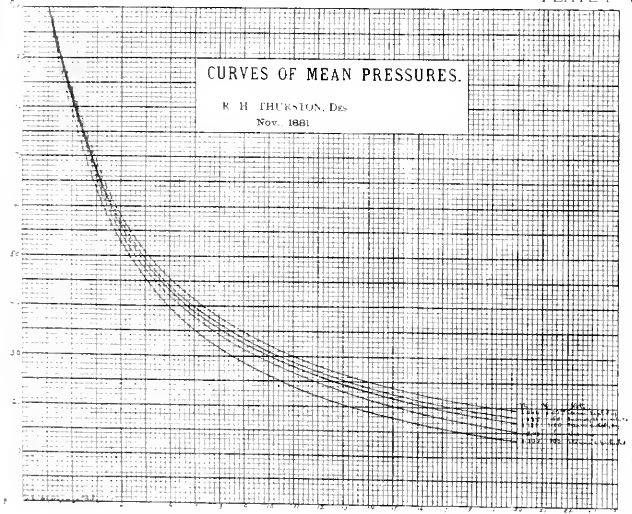


PLATE II

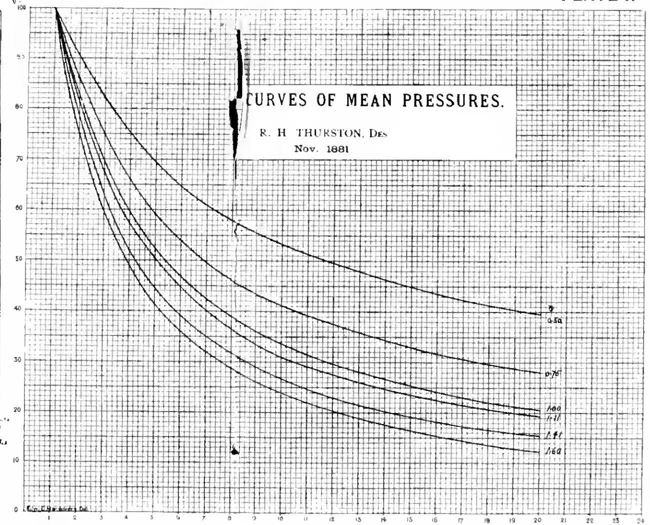
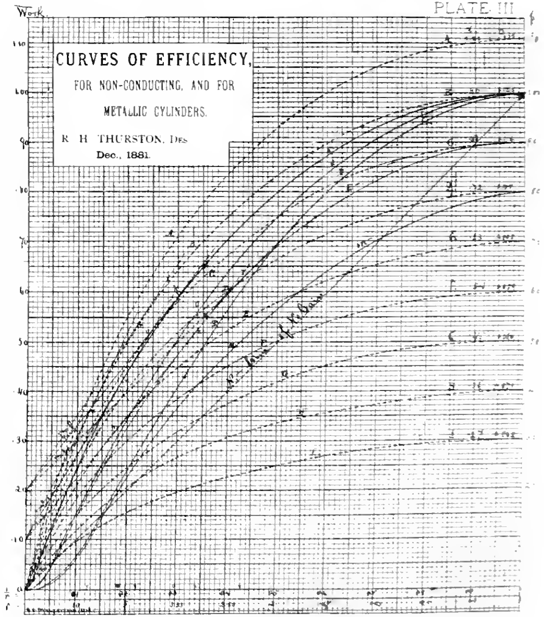


PLATE III



cylinder condensation, h_c, varies as $\sqrt{r}$, and when $h_c = 0{\cdot}1\sqrt{r}$, $h_c = 0{\cdot}2\sqrt{r}$, $h_c = 0{\cdot}3\sqrt{r}$, values which will be found not uncommon in engineering practice. The abscissas of the curves are, as before, measures of weights of steam used.

If, in any case, condensation were so to vary that no gain should be derived from expansion—and such cases are, within a limited range of expansion, sometimes nearly approximated to—the curve of efficiency would become a straight line, N, the "Line of Constant Efficiency," Plate III.

The curves O and P are obtained by altering the vertical scales of L and M so as to give them a common initial point with B and K at $p = 100$ and thus enabling the reader to compare the differences of form of the several lines and of the two kinds of curve more satisfactorily. It will be seen, also, on comparing the second of the two kinds of curve with those derived from experiment on working engines, and to be presented in a succeeding paper, that the Curve of Efficiency here obtained by induction is of precisely the same character as that given by direct experiment.

To construct the theory of these cases of non-adiabatic expansion, the writer has taken the following method: We may take two distinct cases: (1.) That in which, as when the cylinder is unjacketed and unprotected against radiation and the ratio of expansion small or the temperature of exhaust very low, so little re-evaporation occurs that it may be neglected; (2.) That in which, as in jacketed cylinders with wet steam and considerable expansion, nearly all condensation occurs before the point of cut-off is reached and re-evaporation takes place throughout the remainder of the stroke.

Case 1.—It is shown in all works on thermo-dynamics, that the form of the expansion line of steam, either dry and saturated or containing liquid water, may be obtained for adiabatic expansion from approximate equations of the form $pv^n = p_1 v_1^{\,n}$; $p_2 = p_1 r^{-n}$. Since loss of pressure occurs in the metallic cylinder by a transfer of heat, taking place by initial condensation and re-evaporation, and since the amount of this loss is determined, in any given cylinder, by the magnitude of the ratio of expansion, we shall obtain for the value of the pressure in the latter case $p_1^{\,1} = p_1 \left(\frac{v_1}{v}\right)^n \left[1 - f(r)\right]$

The values as well as the form of this function of r, $f(r)$, above, are not yet ascertained. The function is evidently determined by the area

of cylinder surface, time of exposure, variation of temperature of surface and quantity and character of the working steam. The form of $f(r)$ is probably transcendental and it may be exponential. The writer has found that for the ordinary values of the ratio of expansion, as an approximation, we may take $f(r) = ar^m$; m being taken constant.

In this expression a has a value which is determined by the state of the steam at entrance into the cylinder and, if the steam is initially dry, is connected with the exponent n by some definite relation. The value of m is dependent upon the character of the engine and the method of its operation, so far as they determine the rate of variation of the proportions of steam and water during expansion. Given the values of n and of a, m becomes determinable. We have

$$\frac{p_2}{p_1} = r^{-n} - ar^{m-n}; \quad m = \frac{\log.\left[\frac{1}{a}\left(r^{-n} - \frac{p_2}{p_1}\right)\right]}{\log. r} + n,$$

where p_2 is the terminal pressure, a quantity always known when r is known by experiment.

The equation for the expansion line, the working substance being enclosed in a metallic cylinder, is then

$$p = p_1\left(\frac{v_1}{v}\right)^n \left[1 - a\left(\frac{v}{v_1}\right)^m\right]$$

The work done by expansion is

$$\int_{v_1}^{v_2} pdv = p_1 v_1^n \int_{v_1}^{v_2} \left[1 - a\left(\frac{v}{v_1}\right)^m\right] v^{-n} dv$$

The net work is $Wn = p_1' v_1 + \int_{v_1}^{v_2} pdv - p_b v_2$

in which p_b is the back pressure plus friction and useless resistance.

The terminal pressure is given above. Making $r = 1$, we obtain from that equation $p_2 = p_1(1-a) = p_1'$, showing that p_1 is not the initial cylinder pressure, p_1', but the pressure which the same weight of steam would have given if working at the same volume and without condensation in the same cylinder; p_1 exceeds p_1' in the ratio $1 : 1-a$; which ratio measures the working relative values of the same mass of steam with and without condensation.*

Integrating the expression for net work done during expansion,

* If x is the "dryness-fraction" of the steam when worked at full stroke, it having been dry when drawn from the boiler, $p_1' = p_1 x$; $x_1 = \frac{p_1'}{x}$.

$$W_e = \int_{v_1}^{v_2} p dv - p_1 v_1^n \int_{v_1}^{v_2} v^{-n}\left[1 - a\left(\frac{v}{v_1}\right)^m\right] dv, \text{ we obtain}$$

$$W_e = \frac{p_1 v_2}{1-n} r^{2-n} - \frac{p_1 v_2}{1-n} r^{-1} - \frac{a p_1 v_2}{m-n+1} r^{m-n} + \frac{a p_1 v_2}{m-n+1} r^{-1} - p_b v_2 =$$

$$\frac{p_1 v_1}{1-n} r^{1-n} - \frac{p_1 v_1}{1-n} - \frac{a p_1 v_1}{m-n+1} r^{m-n+1} + \frac{a p_1 v_1}{m-n+1} - p_b v_1 r$$

while the total useful work per stroke is $W_n = p_1' v_1 + W_e$.

In this analysis the effect of re-evaporation is entirely neglected as unimportant. It will usually be found, if the writer may judge from his own observation, that it has no important effect in increasing efficiency or in rendering the treatment here adopted inaccurate—except in the determination of final pressures as shown below—for such cases as are included under Case 1.

The equation of these "Curves of Efficiency," as the writer would call them, for adiabatic expansion is

$$y = p_1 \frac{n - r^{1-n}}{n - 1} x.$$

The equation for the present case is

$$y = \left[\frac{r^{3-n} - 1}{1-n} - \frac{a r^{m-n+1} - a}{m-n+1} + 1\right] p_1 x, \text{ nearly.}$$

The mean pressure is then

$$p_m = \frac{p_1 r^{2-n} - p_1 r^{-1}}{1-n} - \frac{a p_1 r^{m-n} - a p_1 r^{-1}}{m-n+1} + p_1' r^{-1}.$$

and the mean effective pressure is

$$p_e = \frac{p_1 r^{2-n} - p_1 r^{-1}}{1-n} - \frac{a p_1 r^{m-n} - a p_1 r^{-1}}{m-n+1} + p_1' r^{-1} - p_b.$$

The mean effective pressure and the work of the machine are maxima when the back pressure, p_b, is fixed, when

$$p_2 = p_1 r^{-n}[1 - a r^m] = p_b,^*$$

provided, as assumed, re-evaporation may be neglected. Then

$$r^{-n} - a r^{m-n} = \frac{p_b}{p_1}.$$

The Ratio of Expansion for Maximum Efficiency is that which satisfies the above equation, and the fraction of stroke completed at the instant of closing the steam valve is $\frac{1}{r} = c$ and its value is that

* In fact, however, re-evaporation—the effect of which is not in such cases usually found to be appreciable in increasing efficiency—prevents the fall of the terminal pressure quite to the value $p_2 = p_b$.

which gives $c^n - ac^{n-m} = \frac{p_b}{p_1}$

Examining the last two equations, it is seen that the smaller the valve of a and the less the values of $m-n$, the more nearly does the value of r approximate to the ratio of initial terminal pressures. It is also evident, both from the analysis and from the graphical construction to be described, that the ordinary variations in the values of n, due to presence of water, do not practically alter the ratio of expansion at maximum efficiency in non-conducting cylinders, as this variation of the exponent rarely exceeds the limits 1·135, 1·125 for such cases.

The steam from well-proportioned and well-managed steam boilers seldom entrains even ten per cent. water. The experiments of the writer* and others give an average of 3·2 per cent. water in steam from boilers not fitted with superheaters, and Hallauer finds less than five per cent., while Isherwood's experiments confirm these figures.

For usual cases, therefore, $n < 1·135$ and $n > 1·130$, no condensation taking place.

Working steam in metal cylinders, however, the case is, as has now been shown, radically different, and the efficiency of the engines and the best ratio of expansion are very greatly altered by variation in both the initial proportion of water entrained and the rate of cylinder condensation. The value of a varies from 0·1 to some much higher figure and the value of m varies from less than unity to at least two. It thus happens that the ratio of expansion, at maximum efficiency, is sometimes reduced to less than one-half that which should be obtainable in non-conducting cylinders.

It is further evident that the great loss of heat thus met with may also be experienced even with superheated steam, as heat may be transferred by conduction and convection as by initial condensation and final re-evaporation. Experiment has shown in fact, as already indicated, that, in some cases, with unjacketed condensing engines, the ratio of expansion at maximum efficiency is not much increased in value by superheating and, hence, that the increased economy noted comes, not from increased efficiency of the machine, but simply from increased range of temperature of working steam and reduced back-pressure; the cylinder-condensation is prevented but the loss of heat

* American Institute Report on Steam Boilers, 1871; JOURNAL FRANKLIN INSTITUTE, 1872.

still occurs, the transfer being effected by a different process.* The above remarks relative to saturated steam are therefore applicable to all fluids used in heat-engines. In fact, in gas-engines, where all vapor is enormously superheated, the loss by exhaust waste thus caused is found to be, sometimes, twice as great as the total quantity of heat which would be demanded were the cylinder made of non-conducting material.

The following cases, illustrating the results of this method of treatment of Case 1, as applied to several selected examples such as are met with in ordinary practice, are given as exhibiting the usual range of values of the quantities involved in the preceding equations.

Character of Engine.	p_1	p_b	a	m	n	r_e
I. Non-condensing engine,	100	20	0·2	1·5	1·115	4·5
II. Condensing, unjacketed,	40	5	0·2	0·5	1·115	2·5
III. " compound, jacketed,	60	6	0·1	1·1	1·125	6·0
IV. " " "	100	5	0·1	0·0	1·135	10·0

The real ratio of expansion is given in all cases where it is not expressly stated that the value given is that of the apparent ratio. In the first three of the above cases, the steam is taken from the boiler dry; in the last case it is so far superheated that it expands as dry steam, all cylinder-condensation being prevented.

Case 2.—The second case is very frequently met with in practice. In this case, initial condensation ceases with the closing of the expansion valve, and in jacketed engines or in engines worked with considerable compression,† even before, and re-evaporation occurs throughout the whole period of expansion. Then, if $b = 1-a$; $a+b = 1$; and if q represent the new exponent, we may write, for the net power delivered,

$$W_n = br^q p_1 v_1 \frac{n - r^{1-n}}{n-1} - p_b r v_1;$$

$p_1 v_1$ measuring, as before, the work obtainable from the same weight of *dry* steam, up to the given point of cut-off, when working at the same ratio of expansion and when, therefore, $p_1' v_1 = b p_1 v_1 = (1-a) p_1 v_1$ as in the first case. This becomes a maximum when

* The now familiar expedients of high speed of piston and of "compounding" engines seem the most successful means yet adopted to check this waste in modern engines. Superheating is also most effective in compound engines.

† Note on The Expansion of Steam and Regulation of the Engine, by R. H. Thurston, Trans. Am. Soc. Mech. Engs., 1881; JOURNAL FRANKLIN INSTITUTE, Oct., 1881.

$$r^{q-1} - \frac{q+1-n}{qn} r^{q-n} = \frac{n-1}{bqn} \frac{p_b}{p_1}.$$

The mean effective pressure is

$$p_e = br^{q-1} p_1 \frac{n - r^{1-n}}{n-1} - p_b,$$

and the equation of the Curve of Efficiency is, for this case of non-adiabatic expansion,

$$y = b^2 r^{2q-2} \frac{n - r^{1-n}}{n-1} p_1 x.$$

For the case of nearly hyperbolic expansion, which is a common one for this class of engines, $W_n = bp_1 v_1 (1 + \log_e r) r - p_b r v_1$, nearly; which is a maximum when

$$\left[\left(q (1 + \log_e r) \right) + 1 \right] r^{q-1} = \frac{p_b}{bp_1}.$$

The mean effective pressure is $p_e = bp_1 (1 + \log_e r) r^{q-1} - p_b$.

The value of q varies from 0 to 0·3, being greatest with most efficient engines.

The ratios of expansion for maximum efficiency are those which satisfy the above equations. The terminal pressure is nearly

$$p_2 = \frac{p_b}{br^q}.$$

The following are corresponding values of a, b and n:

a	0·00	·10	·20	·30
b	1·00	·90	·80	·70
n	1·135	1·125	1·115	1·105

The Curve of Efficiency for this last case has the form

$$y = b^2 p_1 (1 \times \log_e r) r^{2q} x.$$

The value of q lies between 0 and $\frac{1}{2}$ in most cases. The consumption of steam and cost of power in these cases is measured by the volume introduced at the pressure p_1, precisely as with the non-conducting cylinder.

Referring once more to the set of curves of efficiency, Plate III, we may deduce the same conclusions from graphical construction and obtain results far more easily and rapidly. Selecting values of $\frac{p_b}{p_1}$ such as are often obtained with non-condensing and with condensing engines, respectively: $\frac{p_b}{p_1} = ·20$; $\frac{p_b}{p_1} = ·10$, we may determine ratios for maximum efficiency of engine thus: From the points ·20 and ·10

on the axis of ordinates on the scale measuring total work per stroke, draw lines tangent to the several curves, as RT, RV, SV, SW, etc., etc. The points of tangency being found, the values of their abscissas measure the quantities of steam to be used per stroke to give maximum engine efficiency, since the ordinate of any point divided by the abscissa is a measure of the ratio of work done to steam expended in doing it and, for the assumed back-pressures, the *net* amount of work per unit's weight of steam is a maximum at the points just identified.*

On making the construction it will be found that these maxima are found for very nearly the same values of abscissa and, therefore, for the same ratio of expansion, nearly, whatever the dryness-fraction of the steam used in the non-conducting cylinder.†

But, drawing tangents RK, RY, SX, SZ, etc., to curves K, C and M, to determine the best ratios for the metallic steam cylinder, values are formed for r far removed from those just obtained for the non-conducting cylinder and also differing among themselves greatly with the proportion of water present. In the cases shown on the plate, the ratio for the non-condensing engine is decreased to two-thirds and for the condensing engines to less than half that found best for the non-conducting cylinder.

It is to be remembered that the quantity of steam used per stroke, although in direct proportion to the distances "followed" by the steam up to point of cut-off in the non-conducting cylinder, may be in widely different proportion with the metal cylinder. In the latter it varies from nearly an equal proportion at full stroke to, often, a double proportion at high ratios of expansion.

This will be seen more clearly when studying actual engines, as will be shown in a succeeding paper, in which working figures will be given.

The writer concludes from what has been above shown:

(1.) That the work done in a non-conducting cylinder, the fluid expanding adiabatically, varies so little with the proportion of water present that this variation may be neglected by the engineer and he may assume the performance of work to be such as would come of

* This principle was pointed out by Rankine. See Miscellaneous Papers, p. 295, and Shipbuilding, appendix.

† Note that, for curve C, D, etc., the same values of $\frac{p_b}{p_1}$ must be used and the base lines have ordinates, respectively, 0.9, 0.8, etc., those drawn for the curve B.

nearly hyperbolic expansion, while the heat expended may be exactly calculated from the quantity of work, when the latter is known.

(2.) That, in metal cylinders, the work done at any given point of cut-off is nearly the same as in the non-conducting cylinder, but that the quantity of heat and of steam expended in doing it are increased, and usually very greatly increased, by cylinder-condensation if saturated or wet steam is used, or by other methods of transfer of heat to the exhaust and by consequent waste, if superheated steam or other gaseous working fluid is employed.

(3.) That the ratio of expansion at maximum efficiency would be practically unchanged by ordinary variations in the proportion of water entrained with the steam, if it were worked in a non-conducting cylinder, and the value of that ratio, r_e, is very nearly $\frac{p_1}{p_b}$, the quotient of initial pressure divided by the sum of the cylinder back-pressure and other useless resistances.

(4.) That the ratio of expansion at maximum efficiency, when steam or other fluid expands in a metallic cylinder, is more seriously affected by the introduction of water entrained by the steam, and this difference is increased and usually is made very serious by the occurrence of cylinder-condensation, or other method of transfer of heat to the exhaust, when a metal cylinder is used. This ratio becomes, in this case, much less, usually, than $r_e = \frac{p_1}{p_b}$.

(5.) That the quantity of fluid used per stroke in the non-conducting cylinder is in direct and exact proportion with the volume of the cylinder open to the supply-pipe at the instant of closing the expansion-valves and is measured by $\frac{1}{r}$, the reciprocal of the ratio of expansion.

(6.) That the volume of boiler steam worked per stroke in the metal cylinder is *not* in direct proportion to volume of cylinder open to steam at the point of cut-off; but that it is often very greatly in excess of the latter quantity and that it becomes greater, as the ratio of expansion is increased, indefinitely.

(7.) That the ratio of expansion is not a gauge of the volume of steam demanded from the boiler and paid for by the proprietor of the apparatus when the metal cylinder is employed; but that the volume

of steam used or quantity of heat demanded must very greatly exceed the proportion $\frac{1}{r}$ in nearly all actual engines.

(8.) The Curve of Variation of Efficiency above traced, of which the abscissas measure varying quantities of steam used in a given steam cylinder, while the ordinates are proportional to the quantities of work done by those amounts of steam, is a curve of entirely different character and form, and often widely different in location, from the Curve of Adiabatic Mean Pressures or other curve of mean pressures exhibiting the work done by various quantities of steam expanding under given fixed conditions in a non-conducting vessel.

(9.) That no predetermination of the efficiency of any proposed engine, whether of fluid, of machine or of capital, can be made unless the true curve of efficiency can be obtained for the assumed case.

(10.) That the most certain and the most satisfactory solution of any problem of efficiency will be that obtained by first securing the elements of the Curve of Efficiency from actual engines operated in the manner proposed for the case taken.

(11.) That, having obtained by experiment upon any engine, the "Curve of Efficiency," as defined by the writer, the efficiency of fluid, of engine and of capital expended to do a given amount of work, and the quantity of work to be obtained most cheaply from a given engine, may all be obtained for any given set of conditions, and the ratio of expansion, at maximum efficiency, of fluid, of engine and of capital and the ratio of expansion which, with a given plant, gives most work for a dollar of expense of operation, may all be determined with a degree of exactness only limited by the magnitude of the errors of observation.

(12.) That the necessity of following the direction of improvement pointed out and entered upon a century ago, by Smeaton—the protection of the working fluid from losses of heat, by surrounding it with non-conducting surfaces—constitutes the most imperative of all demands to-day made upon the mechanical engineer who may be engaged in designing steam engines.

Hoboken, N. J., Dec., 1881.

TABLE I.

MEAN PRESSURES FOR VARIOUS METHODS OF EXPANSION.

Values of $\frac{p_m}{p_1}$. *Adiabatic Expansion of Steam.*

Ratio of Expansion.	Cut-off: $\frac{1}{r}$	Percentage of Steam and Value of *n*.							
		100 1·135	90 1·125	80 1·115	76 1·111	70 1·105	60 1·095	50 1·085	100 1·333
2	$\frac{1}{2}$	·829	·831	·833	·834	·835	·836	·837	·810
$2\frac{1}{4}$	$\frac{4}{9}$	·785	·787	·788	·789	·790	·791	·793	·754
$2\frac{1}{2}$	$\frac{2}{5}$	·744	·746	·747	·748	·749	·750	·751	·714
$2\frac{3}{4}$	$\frac{4}{11}$	·707	·708	·710	·711	·712	·713	·714	·675
3	$\frac{1}{3}$	·675	·676	·677	·678	·679	·681	·683	·639
$3\frac{1}{4}$	$\frac{4}{13}$	·644	·645	·647	·648	·649	·650	·652	·606
$3\frac{1}{2}$	$\frac{3}{10}$	·633	·635	·636	·637	·639	·641	·643	·600
$3\frac{1}{2}$	$\frac{2}{7}$	·616	·618	·619	·620	·622	·624	·626	·576
$3\frac{3}{4}$	$\frac{4}{15}$	·591	·592	·593	·594	·595	·596	·598	·552
4	$\frac{1}{4}$	·567	·568	·570	·572	·573	·574	·576	·523
$4\frac{1}{2}$	$\frac{2}{9}$	·525	·527	·528	·530	·531	·533	·534	·486
5	$\frac{1}{5}$	·488	·491	·493	·494	·496	·498	·500	·447
$5\frac{1}{2}$	$\frac{1}{11}$	·458	·460	·462	·463	·465	·467	·470	·417
6	$\frac{1}{6}$	·432	·434	·435	·437	·439	·441	·443	·390
$6\frac{1}{2}$	$\frac{2}{13}$	·409	·410	·411	·413	·415	·417	·420	·369
7	$\frac{1}{7}$	·387	·390	·392	·394	·400	·403	·405	·345
8	$\frac{1}{8}$	·355	·356	·357	·358	·360	·361	·363	·312
10	$\frac{1}{10}$	·298	·300	·302	·303	·304	·305	·308	·263
20	$\frac{1}{20}$	·170	·173	·175	·177	·178	·180	·182	·144
50	$\frac{1}{50}$	·080	·082	·083	·084	·084	·085	·086	·063
100	$\frac{1}{100}$	·044	·045	·045	·046	·046	·047	·048	·034

TABLE II.

Mean Pressures for Various Methods of Expansion.

Values of $\frac{p_m}{p_1}$ *for Steam, Air, Gas and Mixtures.*

Ratio of Expansion, r.	Point of cut-off, $1 \div r$	Steam Expanding, Dry and Saturated, n, 1·046.	Moist Air in Compressors, n 1·20.	Steam and Leakage, Actual Engines. n, 0·50	Steam and Leakage, Actual Engines. n, 0·75	Gas and Vapor in Gas Engine, n, 1·60.	Gases. Isothermal, n, 1·00	Gases. Adiabatic, n, 1·41
2	$\frac{1}{2}$	·841	·825	·914	·875	·783	·846	·801
$2\frac{1}{4}$	$\frac{2}{9}$	·793	·787	·888	·844	·733	·804	·753
$2\frac{1}{2}$	$\frac{2}{5}$	·760	·745	·866	·800	·683	·765	·707
$2\frac{3}{4}$	$\frac{4}{11}$	·717	·700	·846	·785	·638	·731	·668
3	$\frac{1}{3}$	·695	·665	·824	·752	·598	·699	·638
$3\frac{1}{4}$	$\frac{4}{13}$	·665	·635	·802	·732	·578	·670	·596
$3\frac{1}{3}$	$\frac{1}{3}$	·652	·625	·796	·716	·568	·661	·588
$3\frac{1}{2}$	$\frac{2}{7}$	·632	·605	·782	·704	·548	.642	·568
$3\frac{3}{4}$	$\frac{4}{15}$	·608	·580	·775	·684	·515	·616	·538
4	$\frac{1}{4}$	·587	·550	·750	·664	·486	·566	·518
$4\frac{1}{2}$	$\frac{2}{9}$	·540	·510	·720	·624	·441	·555	·473
5	$\frac{1}{5}$	·510	·482	·695	·600	·406	·522	·428
$5\frac{1}{2}$	$\frac{2}{11}$	·478	·455	·674	·560	·371	·492	·406
6	$\frac{1}{6}$	·454	·420	·650	·530	·349	·465	·378
$6\frac{1}{2}$	$\frac{2}{13}$	·430	·390	·632	·515	·326	·441	·358
7	$\frac{1}{7}$	·409	·375	·612	·500	·303	·421	·337
8	$\frac{1}{8}$	·372	·340	·697	·468	·276	·385	·302
10	$\frac{1}{10}$	·326	·284	·532	·412	·225	·330	·253
20	$\frac{1}{20}$	·192	·165	·396	·272	·103	·200	·138
50	$\frac{1}{50}$	·091	·074	·245	·193	·050	·098	·060
100	$\frac{1}{100}$	·053	·040	·180	‘134	·025	·056	·032

WHAT IS THE MOST ECONOMICAL POINT OF CUT-OFF FOR STEAM ENGINES, CONSIDERED AS A QUESTION OF FINANCE?

By William Dennis Marks,
Whitney Professor of Dynamical Engineering, University of Pennsylvania.

In the Journal of the Franklin Institute for June, 1880, the writer published a brief paper, determining, in an approximate way, from a purely dynamical point of view, the most economical point of cut-off for steam engines. The limited scope of this inquiry, which confined itself entirely to the ratio of the indicated horse-power to the steam used, provoked an amount of criticism in German, English and American serials which was surprising, and the misapprehension of the limitations of the paper, together with the way in which the intent of the writer was gratuitously assumed, finally caused a reply to Professor Thurston in the *Scientific American* for December 4th, 1880, whose severity has been much regretted by the writer, because of the many and great services which Professor Thurston has rendered in the advancement of rational engineering knowledge, and because the matter arose entirely from a misunderstanding of the writer's intentions on the part of the gentleman named.

As a question of finance the subject becomes more complicated, for the engine owner asks not, How can I save the most steam? but, All the circumstances being taken into consideration, how can I get the useful work which I require most cheaply?

So far as the delivery of useful work by the engine alone is concerned, a method has been given by Professor Rankine, and elaborated by himself as well as others; but, perhaps because of insufficiently profound study of the question from a financial point of view, or because the subject was hardly deemed worthy of his thought, the question was never exhausted by him or his followers.

The shipowner says, How can I obtain the power to drive the propeller most cheaply?

The mill owner says, How can I obtain the power to drive the mill stones most cheaply? and the shop owner says, How can I obtain the power to drive my machinery most cheaply? and as they use the

engine for the purpose of making money, wish to have it designed for that purpose, and care nothing at all for purely scientific considerations.

It is to these men that the writer will endeavor to make reply, giving to a most perplexing question, involving many considerations, at least an approximately correct reply, and indicating a method which, by elaboration and a detailed consideration of the thermodynamic questions raised, will, we trust, enable an engineer to reach an economy of useful power, as yet not *knowingly* obtained by other means than an inspection of the profit and loss account at the end of the year.

In "The Limitations of the Steam Engine," JOUR. FRANK INST., August, 1880, the writer stated as the five points of an engine: (1) concentration of power, (2) economy of steam, (3) regularity of speed, (4) simplicity of design and (5) durability of construction.

In that paper and in his work "The Relative Proportions of the Steam Engine" almost every detail of a steam engine, affecting these points has been discussed at length.

When we do not restrict ourselves to economy of nature's forces economy of steam becomes economy of money.

The following assumptions are made and particulars must be understood in the discussion which follows.

The expansion curve of steam is assumed to be, with sufficient practical accuracy, an equilateral hyperbola.

The steam made by the boiler is to the steam shown by the indicator diagram as 4 to 3. This certainly is not correct under all circumstances, but is an approximation derived from the experiments under favorable conditions upon the Reynolds-Corliss, the Harris-Corliss and the Wheelock Engines at the Millers' Exhibition, Cincinnati, June, 1880 (Report of J. T. Hill, pages 77 and 79), and is nearly the same for both condensing and non-condensing engines. Those in possession of more accurate experimental data can substitute other ratios in each case.

A percentage of the true stroke must be added at each end of the sketch which is made to allow for the clearance which must be determined. The cost of all charges upon the engine and machinery is taken in steam for the sake of convenience, and this proceeding is perfectly proper, since money and steam are convertible.

For the present all reference to the saving of fuel resulting from the diminished number of heat units required to increase the pressure

of steam is *premeditatedly* omitted because we are practically limited by expense to low pressures in ordinary cases.

The constant charges which come upon engine boilers and machinery are as follows:

(1) Wages of attendants upon engine, boilers and machinery.

(2) Interest upon cost of engine, boilers and machinery.

(3) Depreciation of engine, boilers and machinery.

(4) Repairs to engine, boilers and machinery.

(5) Cost of lubrication of engine, boilers and machinery.

(6) Taxes and insurance upon engine, boilers and machinery.

(7) Interest upon cost of shelter and room for engine, boilers and machinery.

Many other charges may exist which the writer has not mentioned and some of the charges mentioned are not applicable is cases where methods of charging cost may differ from that of works and factories engaged in the production of some staple article or of a ship where the engine serves only for propulsion. In every case the distribution of cost must form an individual problem.

The only variable charge when the engine is already established is the cost of the steam, *i. e.*, fuel and water. When engaged in the design of an engine and plant most of the constant charges may be regarded as variables, but not according to any uniform law, and must be considered as separate problems which must be solved from known precedents which vary in different localities.

Let P = the mean effective steam pressure in pounds per square inch.

Let C = the mean effective steam pressure in pounds per square inch required to drive the engine and machinery against frictional resistances only.

Let P_0 = the absolute initial pressure in the cylinder in pounds per square inch.

Let B = the absolute back pressure in the cylinder in pounds per square inch while the exhaust port is open.

Let e = the fraction of the stroke at which steam is cut off.

Let V = the volume of the steam cylinder.

Let c = the fraction of the volume of steam (of the stroke also) equaling the ratio of the constant charges to the total cost of a cylinder full of steam for any assumed time.

Let b = the fraction of the stroke at which compression begins, being measured from the opposite end from which e is measured.

Let k = the fraction of the stroke allowed for clearance.

We can then write

$$\frac{\text{Useful work}}{\text{Cost of work in steam}} = \frac{(P-C)V}{\left[\frac{4}{3}e + c - b\frac{B}{P_b}\right]V} = \frac{P-C}{\frac{4}{3}e + c - b\frac{B}{P_b}} \quad (1)$$

$$\text{But } P = eP_b\left(1 + \text{nat. log.}\frac{1}{e}\right) - b\left[1 - B\left(1 - \text{nat. log.}\frac{b}{k}\right)\right] \quad (2)$$

This value of P as well as that of C could be much more accurately determined by the careful use of an indicator.

Substituting in equation (1), we have

$$\frac{\text{Useful work}}{\text{Cost of work}} = \frac{e\,P_b\left(1 + \text{nat. log.}\frac{1}{e}\right)}{\frac{4}{3}e + c - b\frac{B}{P_b}} - \frac{B\left[1 - b\left(1 - \text{nat. log.}\frac{b}{k}\right)\right] + C}{\frac{4}{3}e + c - b\frac{B}{P_b}} \quad (3)$$

Differentiating with respect to e and seeking a maximum, we have

$$e = \frac{B\left[1 - b\left(1 - \text{nat. log.}\frac{b}{k}\right)\right] + C}{P_b} + \frac{3}{4}\left(c - \frac{Bb}{P_b}\right) \text{ nat. log. } \frac{1}{e} \quad (4)$$

The natural logarithm can be obtained by multiplying the common logarithm by 2·3026, and this transcendental equation must be solved by a series of approximations, beginning with an assumption that

$$\text{nat. log. } \frac{1}{e} = \text{nat. log. } \frac{P_b}{B\left[1 - b\left(1 - \text{nat. log.}\frac{b}{k}\right)\right] + C}$$

and substituting the nearer value of $\frac{1}{e}$ again in the second member of equation (4), and so on, until two successive values of e nearly agree.

As logarithms do not vary rapidly, the approximations required to obtain all the accuracy justified by the data or realizable in practice will be few.

Perhaps how to deduce the value of c is not clear.

Determine the constant charges, in dollars and cents, upon engine and machinery for one day. Regardless of the power, determine approximately, from the first term only of the second member of equation (4), the most economical point of cut-off for steam alone.

With the following formula, determine the weight of water required per horse-power per hour:

W = weight of water per H.-P., per hour, for no cut-off at all.

S = specific volume of steam for pressure P_b.

$$W = \frac{4}{3}\,\frac{859380\,e \times \frac{1}{e}}{S\left\{e\,P_b\left[1+\text{nat. log.}\frac{1}{e}\right]-B\left[1-b\left(1-\text{nat. log.}\frac{b}{k}\right)\right]\right\}} \qquad (5)$$

(See the Limitations of the Steam Engine, JOUR. FRANK. INST., Aug., 1880.)

With this determine the cost of fuel and water for full stroke for the required horse-power per day—remembering that $\frac{4}{3}$ is an assumed quantity which, at the best, is only approximately correct.

We will then have

$$c = \frac{\$\text{constant charges per day}}{\$\text{constant charges} + \$\text{cost of fuel and water per day}}$$

c can be redetermined more accurately after e is more accurately determined by its use.

An inspection of equation (4) reveals many interesting facts.

We observe that an increase of the initial pressure or a diminution of the back pressure renders the cut-off of steam earlier. Also that a diminution of the back pressure has much more influence than an increase of the initial pressure. We further observe that any diminution of the frictional resistance of the engine and machinery has a great diminishing effect on the point of cut-off and that the constant charges will largely add to the distance of the point of cut-off from the beginning of the stroke, their influence being particularly felt whenever B and C are small.

Economy of money will give increased concentration of power and simplicity of design.

Regularity of speed, under all circumstances, demands an automatic cut-off, as it is the only effective expedient we now know for that purpose.

The condition is that the most economical point of cut-off shall be determined, and with that an engine designed for the required power.

A lessened demand for power will result in an earlier cut-off, and although the steam is not used quite so economically per horse-power, less steam is used, and the result is a saving of coal.

With an engine already erected, the only means of attaining the most economical point of cut-off is to change the load, the back pressure or the initial pressure.

The quantity C shows the great importance of reducing the frictional resistance in the transmission and accomplishment of work.

To determine the most economical point of cut-off for an established engine, the following method can be used:

(1) Determine the mean absolute back pressure.

(2) Determine the mean effective pressure required to drive engine and machinery against friction at the required speed.

(3) Add (1) and (2) together, and divide by the absolute initial pressure, the result will be the approximate cut-off for the greatest economy of steam.

(4) Determine the constant charges on engine and plant for some assumed time.

(5) Determine the cost of fuel and water required with the given pressure and approximate cut-off by dividing $\frac{4}{3}$ of 859380 by the mean effective steam pressure when doing useful work, multiplied by the specific volume of steam at the initial pressure, and further multiplying this result by the number of hours in the assumed time and the horse-power required. Add the cost of fuel and water to the constant charges, and divide the constant charges by the sum, the result will be the ratio of the constant charges to the total cost of steam and transmission of power.

(6) From this ratio subtract the product of the absolute back pressure during an open exhaust by the fraction of the stroke for compression, divided by the absolute initial pressure, and multiply the result by $\frac{3}{4}$ of the natural logarithm of $\frac{1}{e}$, e being taken at the value given by paragraph (3).

(7) Add the results of (3) and (6) together to obtain a first approximation to the cut-off required.

(8) Find the natural logarithm of the new value of $\frac{1}{e}$, and with

this proceed as in paragraphs (6) and (7) until the successive values nearly coincide.

(9) Should the final value of e differ greatly from that assumed from paragraph (3), a redetermination of the ratio of the constant charges to the total cost of steam and transmission of power (see paragraph 5) may be necessary, and another series of approximations to the value of e will also become necessary.

In closing, the writer wishes to say that he does not feel that this topic is by any means exhausted, and that he trusts that some one will endeavor to give the correct solution of the problem a simpler form.

Philadelphia, Feb. 3, 1882.

CONTRIBUTION TO THE HISTORY OF THE LINK MOTION.

By JOHN L. WHETSTONE, Esq., Cincinnati, Ohio.

To the Committee of Publication of the Franklin Institute.

GENTLEMEN:—In view of the recent proposed changes in the system of link motion for steam engines it seems very desirable that the work already done in the same direction should be recorded. I therefore wrote to my friend Mr. Whetstone for his recollection of a system originated by him, whereby he obtained with one eccentric a reversing link, and employed the motion of the cross-head to give the lap and lead. Also for his method of plotting the ordinary link motion. The paper now submitted has been sent to me for such use as I may desire to make of it. During the time that he was engaged on the work he describes I had full knowledge of his methods, as I was with him in the same establishment, being foreman of the locomotive shop in which he had charge of the drawing room. Mr. Whetstone was one of the most brilliant of the mechanical engineers who at that time turned their attention to the locomotive, but the necessity arising for him to take charge of important interests not involving so directly an attention to this branch of mechanical engineering, his attention has in some measure been directed from it. Submitting his paper with this note as explanatory, I am,

Yours truly, COLEMAN SELLERS.

In the years 1851-2 the writer assisted in the designing and con-

structing some locomotive engines for a special purpose, and the arrangement of the valve gear was especially assigned to him. From the peculiarity of the general arrangement of the machinery it was found impracticable to use more than one eccentric for operating the valves of each engine, and it was necessary to use a valve with considerable lap. There being barely room for one eccentric for each engine on the driving axle, the device of shifting a lead eccentric across the axle for the purpose of obtaining lead for the forward and backward movements could not be applied. The valve gear which was finally adopted was substantially the same as represented in Fig. 7, with slight modifications. The eccentric was set so as to be at half throw when the crank pin was at the ends of the stroke or at the dead point, and connected by a rod to an arm on the rocker shaft having at its other end a double arm, carrying a link bar for the purpose of giving reversing movements to the valve. The position of the rocker arm and link bar was therefore the same when the crank was at either end of the stroke, viz., that shown in the Fig. 7, at *A B C*. For the purpose of giving the advanced movement requisite for the lap and lead of the valve, the shifting or reversing rod (one end of which is properly swiveled to the link bar) is connected to the fulcrum *F* of a lever, the longer arm of which is suitably attached to the cross-head of the engine, the shorter arm being geared to the valve rod at *G*, or to any suitable device necessary to transmit the movement to the valve. The length of the arms of this lead-lever are such that when the fulcrum *F* is at the half throw of the eccentric the upper wrist of the lever *G* is removed from the centre line *H K* to the extent of the lap and lead of the valve, the longer end connected with the crosshead then at one end of the stroke, and if the cross-head be at the other end of the stroke, the upper wrist will be as far removed to the opposite side of the centre line.

It will also be observed that the position of the wrist operating the valve rod will remain the same, in whatever part of the link bar the reversing bar or rod *D F* may be situated, whether in full gear forward or backward, or at any intermediate point, and the lead of the valve will be the same at both ends of the stroke. The throw of the eccentric for this valve gear will be shorter than the travel of the valve, inasmuch as part of the valve movement is obtained from the crosshead. In practice it is found that about two-thirds of the lead of the valve is obtained from the crosshead, and

the eccentricity of the eccentric is lessened to that extent. At first sight it would seem as though the whole was due to the cross-head, but it must be borne in mind that during the last half of each stroke of the piston the eccentric motion is in a direction opposite to that of the crosshead, thus combining the two movements to extend the travel of the valve. The effect of this combination is to accelerate the movement of the valve at the opening of the ports, and to retard it at and towards the end of the throw of the valve, thus giving a longer admission of steam with a given lap of valve then by the eccentric motion alone. It would be quite practicable to operate the rocker arm link of one engine from the crosshead of the opposite engine, the lead being obtained from its own crosshead, and probably the greatest objection to such an arrangement would arise from the fact that the disability of one engine through an accident would render the valve movement of the other engine inoperative.

In 1853-4 the link motion, as it is termed (combining the movement of the forward and backward eccentrics), began to be generally adopted on locomotives, in place of the hooked or forked eccentric rods previously employed for reversing movements of the engine, in connection with separate eccentrics and valves arranged for the purpose of cutting off the steam at different parts of the stroke. The almost universal employment of the link motion at the present time in engines of every description, which are required to run at high rates of speed, affords evidence of its acknowledged superiority over other forms of valve gear.

At the time of their first introduction, the great difficulty of adjustment of the working parts so as to produce equality of cut-off or suppression of the steam on both strokes of the piston at all desired positions of the link gear operated as a serious objection to their use. The writer being then engaged in designing and constructing locomotives in a large establishment determined, if possible, to devise a system of arrangement of the various parts of a link gear which should secure the above results. The difficulty of this problem is enhanced by reason of the variety of elements modifying the movements of the valve, and which must be taken into the account in its solution—as for instance the proportionate lengths of the main connecting rod and crank, the lap and lead as compared with the travel of the valve, length of rocker arm, radius of link, all of which to some extent require modifications of the link gear. Adopting as a motto the aphor-

ism of Lord Bacon that Nature can only be conquered or rendered subservient to our purposes by implicit obedience or compliance with her laws, the writer determined to find the several positions of the link requisite to produce suppression or cut-off at the principal points in the stroke of the piston, in forward and back gear, and then endeavor to arrange the reversing gear, so as to maintain the link in the position so ascertained. For this purpose the positions of all the main lines and centres of the several parts of the engine involved were accurately laid down of full size on a drafting table, viz., the centre line from cylinder to driving axle, showing centre of crosshead wrist at each end of the stroke, and at half stroke, and three-quarters and seven-eighths stroke each way; they are described by the centre of wrist on rocker arm to be operated by the link on which are marked the lap and lead for the valve, as previously determined upon; the centre line from driving axle bisecting the arc described by the rocker arm in its travel. In the accompanying illustrations, this last named line is coincident with the centre line from cylinder to driving axle. The circles

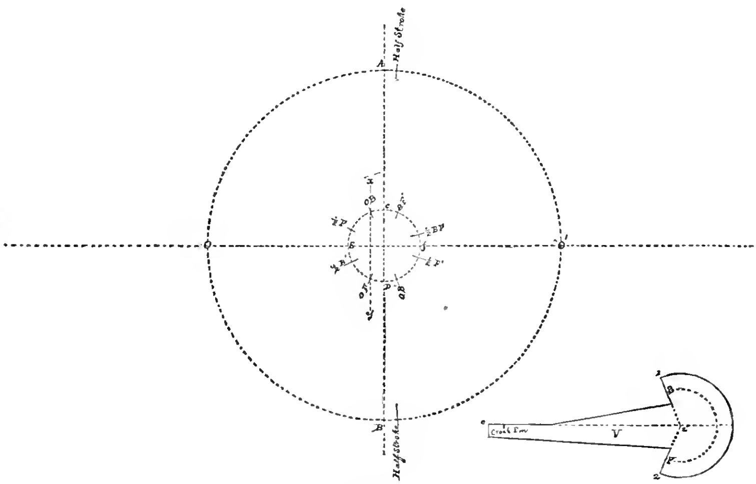


Fig. 1.

O A O′ B, Figs. 1, 2, represents the circuits described by the crank wrist, and *D E e f* the circuit described by the centre of the two eccentrics. The positions of the crank pin at the different parts of the stroke are obtained by using a tram or beam compass set to the length of the distance between the centres of the driving axle and that of the crosshead wrist at half stroke shown at ½ on line *G H*, Fig. 3 (thus

representing the length of the main connecting rod), one leg of tram being placed at the desired point in the stroke, with the other leg arcs are described intersecting the crank circle $O\ A\ O'\ B$ at points marked half stroke, Fig. 1, and $\frac{7}{8}F$, $\frac{7}{8}B$, $\frac{7}{8}F'$, $\frac{7}{8}B'$, Fig. 2, the position of the forward and back eccentric are determined by drawing a line, $A\ B$, Fig. 1, through the centre of the driving axle at right angles to the centre line extending to the rocker arm to be operated by the link, and another line, $X\ Y$, parallel to $A\ B$, and distant from it equal to the amount of lap and lead to be given to the valve, the points of intersection with the circle $D\ E\ c\ f$ will represent the centres of the two eccentrics when the crank pin is at O at the end or commencement of the stroke.

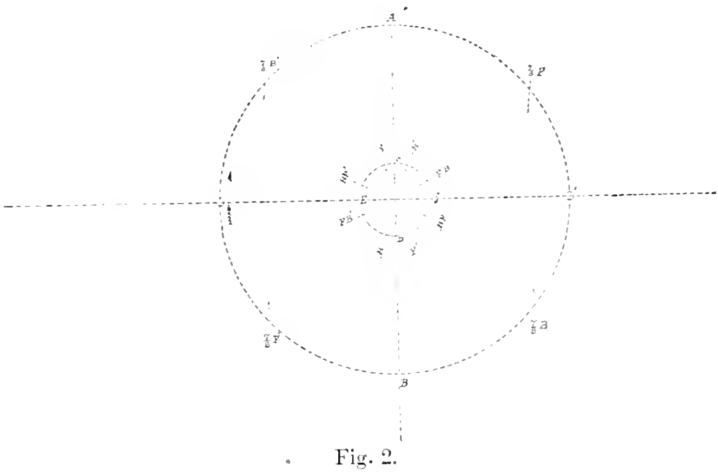


Fig. 2.

A template V, Fig. 1, is made of sheet metal or stiff card board, having a small hole at z, and with edges coincident with the crank pin, and with radial lines z 1, z 2, passing through the centre of the eccentrics $F\ B$, and by inserting a needle through the small hole z into the centre of the driving axle, and placing the edge $z\ c$ at the intersections representing the crank pin at various portions of the stroke, the positions of the eccentrics at each position of the crank can be marked with a pencil or pen intersecting the circle $D\ E\ c\ f$. Thus the forward and back eccentrics respectively will be at $O\ F$, and $O\ B$, Fig. 1, when the crank is at O; at $\frac{1}{2}\ F$, $\frac{1}{2}\ B\ F$ when crank is at half stroke; at $O\ F'$ and $O\ B'$ with crank at O' and at $\frac{1}{2}\ F'$ and $\frac{1}{2}\ B\ F'$, with crank at the other half stroke. By a similar procedure the rela-

tive positions of the eccentrics at any other desired point of the stroke, say seven-eighth stroke, is obtained as shown in Fig. 2, where F and $B\ F$ are the centres of the forward and back eccentrics with crank at $\frac{7}{8}\ F$, moving in the direction of the arrow, and F' and BF', with crank at $\frac{7}{8}\ F'$, and B and $F\ B$, with crank at $\frac{7}{8}\ B$, and B' and $F\ B'$, with crank at $\frac{7}{8}\ B'$, moving in the opposite direction.

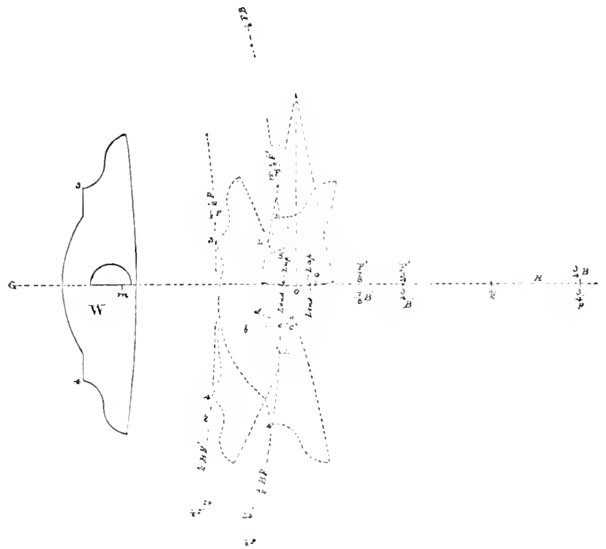


Fig. 3.

Another template W, Fig. 3, is made with a curved edge having a radius equal to the distance from the points C or D, Fig. 1, 2, to the rocker arm wrist when at mid throw, the corners 3 4 representing the centres of the knuckles connecting with the eccentric rods, a hole being cut through the template, one side of which coincides with a straight line dividing the link into two equal portions. The length of the eccentric rods is obtained by placing the curved edge of the link template opposite to the corner 3 in contact with the rocker arm wrist centre when at mid throw, at O', Fig. 3, and moving the body of the template to a position where the same tram will touch the points D, Figs. 1 and 3, on the template, and C, Fig. 1 and 4 on the template. With the length thus obtained as a radius, and the centres at

the intersection $\frac{1}{2}$ F and $\frac{1}{2}$ F', Fig. 1, describe the arcs $\frac{1}{2}$ F, $\frac{1}{2}$ F' above the centre line G H, Fig. 3, and from the centres $\frac{1}{2}$ B F and $\frac{1}{2}$ B F', Fig. 1, describe below the centre line the arcs $\frac{1}{2}$ B F and $\frac{1}{2}$ B F', Fig. 3. The lap of the valve having been marked as shown in Fig. 3, the template W is now placed with its corner 3 in contact with the

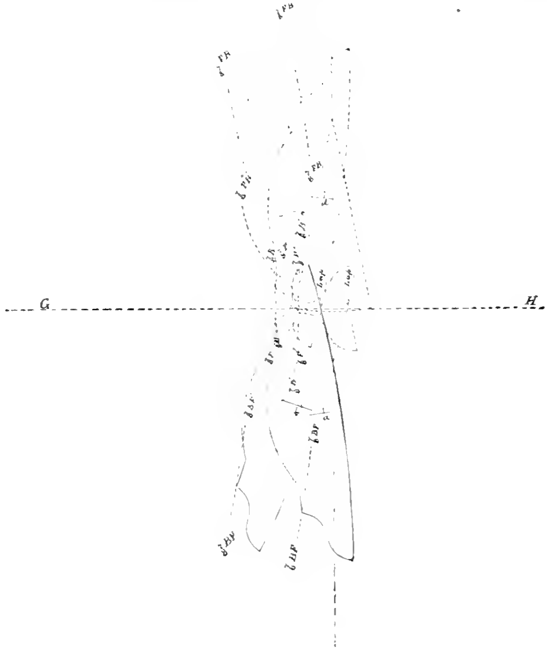


Fig. 4.

arc $\frac{1}{2}$ F, and corner 4 in contact with arc $\frac{1}{2}$ B F, and moved along until it reaches the place indicated in Fig. 3, where the curved edge cuts the point marked *Lap*, being the point of suppression or cut-off, and with a pen or pencil the line a b is drawn along the straight side of the hole in the template. By a similar process, using the arcs $\frac{1}{2}$ F' and $\frac{1}{2}$ B F' the line c d is obtained, and their intersection at e determines the vibrating centre of the link and its position to cut-off at half stroke on the forward movement of the engine in the direction of the arrow, Fig. 1. By a similar process the intersections at g are obtained, being the position of the link-vibrating centre for the backward movement of the engine. The vibrating centre of the link should be marked on the template at m.

The next step to be taken is to obtain the position of the vibrating

centre of the link in order to cut off the steam at seven-eighths stroke of the piston in forward and back gear. For this purpose, with the centre F, Fig. 2, and the length of eccentric rod for radius as before, the arcs $\frac{7}{8}$ F, Fig. 4, is described downwards from the centre line and a little above it, each end of the arc being suitably marked to identify it, and from the centre B F, Fig. 2, the arc $\frac{7}{8}$ B F, Fig. 4, is described at some distance below the centre line, and suitably marked. By traversing the corners 3 4 of the link template W along these arcs until the curved edge intersects the lap point, the position of the vibrating centre in order to effect cut-off at seven-eighths stroke is found to be at a, Fig. 4. By describing the arcs $\frac{7}{8}$ F' and $\frac{7}{8}$ B F', Fig. 4, from the centre F' and B F', Fig. 2, and traversing the template W as before, the position for the vibrating centre of the link for cut-off at seven-eighths stroke in forward gear is found to be at b. By similar procedure the corresponding positions for back gear are found at c d, Fig. 4.

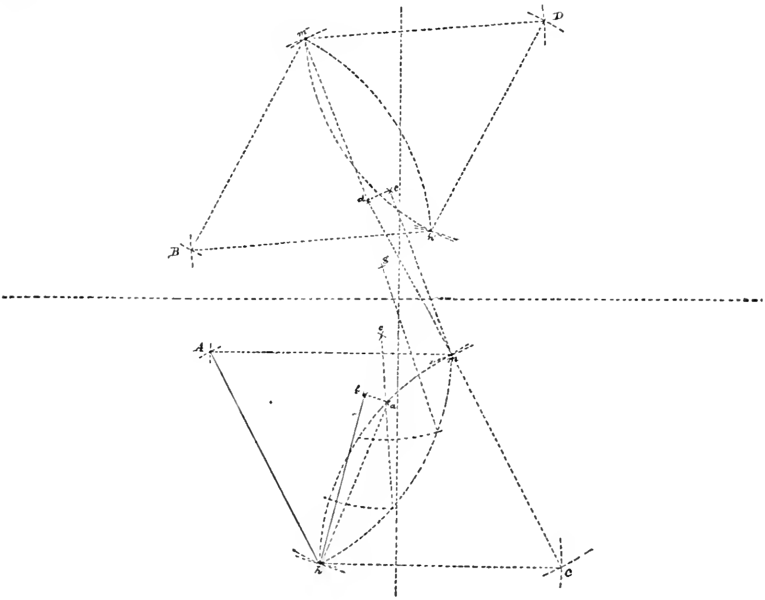


Fig. 5.

Having now ascertained the precise vibrating centre of the link, and its required positions to effect equal suppression of steam at the most important parts of the stroke both in forward and back gear, it

now remains to adjust the reversing gear to meet those requirements. Fig. 5 represents at *a b c d e g* the several points determined in the other drawings. The length of the suspending or sustaining bar on which the link vibrates being determined upon, with this length for radius the intersecting arcs *h* and *h'* are described from *a* and *b* as centres, and *m* and *m'* from the centres *c* and *d*. Then with the centres *h m* with the length of the lifting arm for radius the intersecting arcs *A C* are described, and from *h'* and *m'* the intersecting arcs *B* and *D*, all which points indicate a possible position for the reversing shaft. The reversing shaft may be located at any of the points *A B C* or *D*, though in practice the writer always adopted that shown at *A* in all the locomotives constructed under his direction. In practice all the operations were performed on one drawing by describing the arcs of the eccentric rods in different colored inks, and

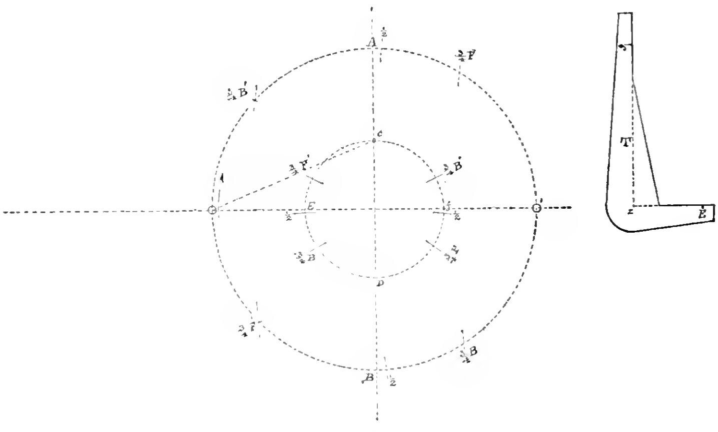


Fig. 6.

with dotted or full lines to avoid confusion of lines, and the indications of the diagrams were fully realized in practical operations of machinery constructed in accordance therewith. To ensure against possible errors in the drawings, every different class of valve gear was tested on a full-sized adjustable working model before commencing on a working machine. With a well-constructed working model capable of adjustment to all the varied positions and proportions for cranks, eccentrics, rocker arms, connecting rods, etc., with links of proper radii, the position for the vibrating centre of the link at the various points of suppression or cut-off can be readily obtained

after careful adjustment of the eccentrics and rods so as to obtain the correct lead to the valve, when the piston is at either end of the stroke, by moving the vibrating centre of the link on the central line as *G m*, Fig. 3, until the position *m* is obtained such that with the piston at either half stroke, when the link is moved to the point of suppression for either stroke, the vibrating centre shall be at the same point, which can be ascertained after a few trials. The exact position on the link for its vibrating centre being determined, if the crosshead is set at three-fourths or seven-eighths stroke for each stroke, the position of the vibrating centre of the link can be noted for the point of suppression at each stroke, both in forward and back gear, and the position for the reversing shaft can be determined as explained for Fig. 5.

Fig. 7 represents the general arrangement of rocker arms, link and crosshead attachment for a valve movement with a single eccentric, or its equivalent, which in this case, Fig. 6, is a wrist on the end of one arm extending from the crank pin toward the axle centre, and adjusted so as to occupy the position marked *C* at right angles to the line from the axle centre to the rocker arm at mid-throw when the crank pin is at *O*. The template *T* is used for marking the positions of the wrist *C*, Fig. 6, at various parts of the stroke, as in the case before described, and the template *a b c d e f g h*, with a hole corresponding to the rocker shaft is used to mark the positions of the link at corresponding parts of the stroke, the dotted lines *k m*, *n m*, represent the positions of the lead lever to cut off at both half strokes. Now with the centre *p*, and the shifting bar for radius, the arc *s t* is described, whose intersections 2 3 show the proper position for the shifting bar to cut off at half stroke in forward and back gear, and with centre *r* and same radius, the arc *u v* is described for the purpose of determining the cut-off points, 4 5, for the other half stroke. By marking off on a straight edge the length of the shifting bar and the point of suppression *D*, and laying this straight edge at *p* 2, *p* 4, the points of suspension *c′ d′* are obtained. By similar process the points *a′ b′ e′ f′ g′ h′* are ascertained, being the points of suspension for cut-off at half stroke and three-quarter stroke for both strokes in forward and back gear. From these points as centres the intersecting arcs *i′ k′ m′ n′* are described, with the suspending bar for radius, and by bisecting the chords *i′ m′* and *k′ n′*, the centre for the reversing shaft *x* is found, and the length of reversing arm determined. The reversing shaft may be placed above the centre of the rocker shaft, and its position ascertained by

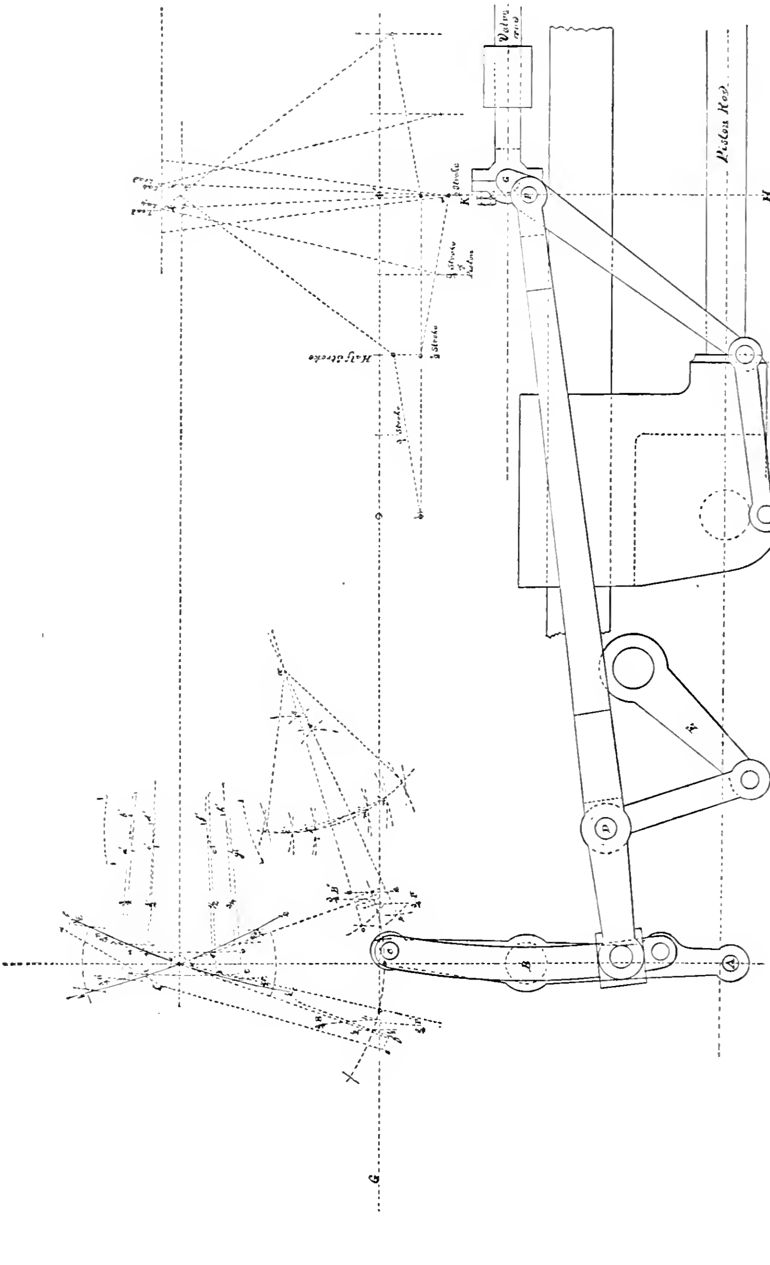


Fig. 7.

similar process; but when practicable the position below the rocker shaft is preferable. This style of valve gear is more especially applicable and adapted to freight engines having small drivers, inasmuch as all the valve gear is readily within sight and reach, and with a given lap and travel of valve a longer admission of steam in full gear is attained, with the same range of cut-off as in the shifting link. The uniformity of lead at all positions in gear is not favorable to the attainment of the highest speeds required in passenger traffic.

A NEW THEORY OF THE SUSPENSION SYSTEM WITH STIFFENING TRUSS.

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The points in which the present discussion differs from the theory generally received, are as follows:

The ordinary suspension system is assumed to consist of cable, truss and stays. The cable is supposed to carry the entire dead and full live load. The stays are inserted for additional stiffness at the flanks, while the truss is constructed to merely rest upon the abutments, and it is assumed that it so distributes any partial loading that the curve of the cable remains practically unchanged. That is, the curve of the cable is assumed, to be parabolic and it is assumed that the truss distributes any partial load *so as to make it take effect upon the cable as a uniform load*, thus preserving the parabolic shape.

In opposition to this generally received theory, we maintain in our present discussion that the curve of the cable does *not* remain parabolic, but takes the curve of equilibrium due to the loading. We thus claim to obtain a more accurate, rational and scientific theory of the stiffening truss. We also discard stays entirely, upon the ground that they are unnecessary. Finally, we suppose the truss firmly bolted down at the ends, so that the tangent to the curve of deflection at the ends is always horizontal, and that it supports its proper portion of the live load.

All of these points are too obvious to need defence. The common assumption that the curve of the cable remains always a parabola, and that the truss distributes the load *uniformly*, every engineer knows to

be false. Such an assumption cannot fail to lead to an incorrect theory, and it is not to be wondered at that trusses proportioned in accordance fail to give satisfactory rigidity. One only needs to watch the oscillation and deflection due to a passing load, to realize how erroneous such an assumption must be, yet it lies at the bottom of every received theory.

As to the stays, we regard their use as a confession of imperfect design. Cable and truss—the one to support and the other to stiffen —are sufficient for a rigid system. The introduction of stays renders the combination indeterminate as to its strains and impossible of accurate adjustment. If the material in the stays of many of our suspension bridges were properly put into the truss there would be a positive gain of rigidity.

As to the truss, while it has been recognized that it is the main element of rigidity, owing to false ideas of economy and a superstitious dread of "temperature strains," the very rigidity which is sought to be secured by its use is often sacrificed by the introduction of hinges and allowing the truss to swing free; or, at most, merely rest upon the masonry. There seems no defence for such practice. As stiffness is what we wish, let us take the best means to secure it. The girder fastened down horizontally at both ends is the stiffest construction we can employ. This need not prevent the use of friction rollers at the ends. As to temperature strains in general, they can be easily calculated, are found not to be excessive and it is far better to allow for them by proper cross-sections than to sacrifice rigidity in order to avoid them and then insert all the material, apparently saved, in the shape of stays.

We have allowed ourselves the following preliminary remarks in order to emphasize the points of difference of the present discussion and to point out wherein it is new. The formulæ here given are, so far as we know, entirely new, and the method of calculation we believe to be more exact than any hitherto proposed.

Composite System.

A very common construction for long spans is that shown in Fig. 1. Such a structure we may call "composite"—that is, it consists of two different systems which act together. Fig. 1 represents the most important of these, known as the "suspension system." It consists of a flexible chain or cable which is stiffened under the action of partial

loads by a truss. The truss is slung on to the cable by suspenders and may be of any design, either double or single intersection, Post, Pratt, etc. The cable carries the entire dead weight of the truss—that is, the suspenders are screwed up until the ends of the truss just bear on the abutments. The office of the truss is then mainly to stiffen the cable and prevent change of shape and oscillations, due to partial and moving loads. It also acts to support a share of the moving load. There are usually side spans at each end. In any case the cable is not attached to the towers but passes over rollers at the top and is carried beyond and firmly fastened to large anchorages of masonry.

Defects of the System.

The principal defect of this system is its lack of rigidity. The cable possesses no inherent rigidity except such as is due to its weight and inertia, and any stiffness which it may have, therefore, is due, almost entirely, to the truss.

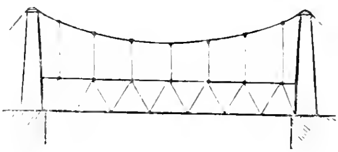

Fig. 1.

A second disadvantage is that a rise of temperature, by decreasing the deflection of the cable, throws considerable load upon the truss. To obviate this objection, the truss is often hinged at the centre and placed on rollers at the ends.

Advantages of the System.

It is evident from the preceding that the system is most advantageous for very long spans. The cable then carries the dead weight in the most advantageous manner and, by reason of its own very considerable weight in such case, resists in some degree the deforming action of partial loads. The truss is then very light compared to what it would have to be if there were no cable.

Stays Unnecessary.

The system is accordingly, in practice, applied only to very long spans. But owing to a lack of rigidity even in such cases, additional stiffness is sought to be obtained by the introduction of *stays*, reaching from the top of the tower to various points of the truss, as shown in Fig. 2. The use of these is not to be recommended, for two reasons. They render the correct determination of the strains indetermi-

nate. A load at any point may be carried entirely by the suspender and stay at that point, or by the suspender and truss, or by the stay and truss. It is impossible to tell exactly the duty performed by each, and even if it were, it would be impossible to so adjust the several systems that they shall take their proper share. If such adjustment were possible it would not last. Variations of strain, set and elongation of the metal, shocks and vibrations, and rise and fall of temperature, would constantly disturb the adjustment.

In the second place, the stays are unnecessary. The truss is a rigid construction in and of itself, and ought to render rigid any system of which it is a member. If properly proportioned, then, the truss is sufficient. Stays are superfluous additions and their use is unscientific. Their employment is a confession of improper design in the truss. We shall, therefore, suppose in what follows that no stays are employd.

Truss should be Fixed Horizontally at the Ends.

As the main object of the truss is to secure rigidity, that construction of truss should be adopted which promises the greatest stiffness. The truss should, therefore, be securely and firmly bolted down at several successive points at the piers and abutments, so that, under all circumstances, it is *fixed horizontally at the ends.* It should also be *continuous and without hinge at the centre.*

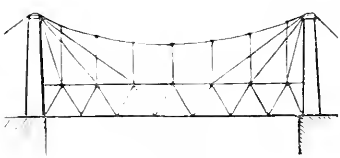

Fig. 2.

It may be objected to this, that in such case there are strains due to change of temperature. This is quite true. But such strains can be accurately found and the truss proportioned to withstand them.

The common practice of hinging the truss in the centre and placing it on rollers at the ends, in order to avoid temperature strains, is at the expense of rigidity. Moreover, nothing is gained in economy when the endeavor is made to make good this loss of rigidity by the employment of stays. The material saved in the truss and cable is balanced by the material in the stays, and the result is a shaky and unscientific combination. It is far better to put the material of the stays into the truss, where it is needed to resist temperature strains, and do away with all hinges and rollers. We thus obtain the greatest stiffness the system admits of, and have a combination the strains in

which can be accurately determined, easy of adjustment and which once adjusted will remain so.

Instead of rollers at the ends, a *sliding joint* at the centre of the truss may be permitted, since such a joint, if properly constructed, does not break the continuity of the flanges, and hence does not impair the rigidity, while it does reduce the strains due to temperature. Rollers may also be used, provided that they do not affect the condition that the truss shall be horizontally fixed at the ends.

Best Form of Suspension System.

The best form of the suspension system then, and the one which we shall investigate in the following pages, consists simply of truss, cable and suspenders, as shown in Fig. 1. The truss is assumed to be fixed horizontally at the ends and to have, if desirable, rollers or a sliding joint at the centre or ends, which does not interfere, however, with the continuity of the flanges at that point.

The truss may be of any of the usual patterns. The flanges are usually horizontal and the bracing either single or double intersection with vertical posts, or triangular. This, however, is by no means necessary. Any form of truss may be employed, whether the flanges are horizontal or parallel, or not.

It is necessary to point out that such a system as the above does not at present exist. Of the large suspension bridges in existence, none are fixed horizontally at the ends, and most employ stays and are hinged at the centre. Our discussion and formulæ, therefore, *do not apply to such*, and will not enable one to find the strains in them. Indeed, from the preceding, we see that it is not possible to find the strains in them with any degree of certainty, and hence it is useless to devote space here to their discussion. It is not, therefore, surprising that the system has been considered, and is still considered, unsatisfactory in railroad practice, except under certain regulations as to allowable speed and load and, as regards its calculation, still more unsatisfactory in theory.

We claim that the system proposed secures the greatest rigidity possible to the combination and admits of satisfactory calculation, and is, therefore, not only the best but the only scientific combination. Finally, that the bugbear of temperature strains is one only in appearance, since what is saved in the truss and cable, by the ordinary system, is lost in the stays.

Theory of Composite Structures Generally.

Before proceeding to investigate the suspension system, we shall illustrate the principles which must govern the discussion of any composite system.

Let λ_1 be the alteration in length, per unit of length, due to the strains in one system, and λ_2 that due to the strains in the other. Then, in order that there may be the same unit strain at all points in both members, we must have

$$\lambda_1 = \lambda_2 \tag{I}$$

But a common unit strain in both systems implies that both act together and are made of the same material. Equation (I), then, expresses the condition that both systems reach the elastic limit simultaneously, *provided they are both made of the same material.*

In any special case, as we shall see hereafter, λ_1 and λ_2 can easily be found in terms of the depth, span and deflection. Since the span and deflection are the same for both systems, they will cancel in equation (I) and we shall then have from it the relation that should exist between the depths, for the least amount of material. Equation (I), then, under the limitation of a common material, enables us to determine the dimensions of each system, in order that the elastic limit may be simultaneously reached by both—that is, in order that the two may act together as one system.

But whether both systems are made of the same material or not, or whether the elastic limit is reached simultaneously or not, still, if both systems are rigidly connected, they must have a common deflection at each point of connection. One system cannot deflect without causing the other to deflect an equal amount. If then δ_1 is the deflection of one system and δ_2 that of the other, we have

$$\delta_1 = \delta_2 \tag{II}$$

Since the deflection varies directly as the load, the ratio $\frac{\delta_1}{\delta_2}$ found from equation (II) in any special case, will give the ratio of the loads. If then we know the total load, we can find the load carried by each system.

The two principles expressed by equations (I) and (II) lie at the foundation of the discussion of all composite structures.

Change of Length.

The coefficient of elasticity, E, is that theoretical unit force which would stretch a piece an amount equal to its original length, if the law of proportionality of elongation to stretching force were to hold good throughout such extreme elongation.

Thus if S is the stretching force and F the cross-section, $\frac{S}{F}$, is the unit force. If the elongation produced by this unit force is λ per unit of length, and the length of the piece is L, the elongation due to the unit force $\frac{S}{F}$, is λL. It will then, according to the assumed law, require as many times $\frac{S}{F}$, to produce the elongation L, as λL is contained in L.

Hence,
$$E = \frac{S}{F} \times \frac{L}{\lambda L} = \frac{S}{F\lambda}.$$

From this we have for the elongation per unit of length

$$\lambda = \frac{S}{FE} \qquad \text{(III)}$$

From this equation we can always find the elongation per unit of length, λ, when the cross-section of the piece, F, and the applied force, S, are known.

Application of Preceding Principles.—Illustration.

Let us take as an illustration of these principles and of the use of our fundamental equations (I) and (II) a simple composite structure, represented in Fig. 3.

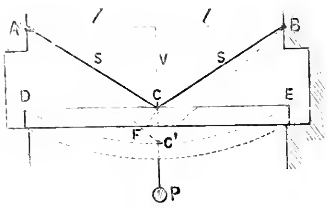

Fig. 3.

It consists of a beam, DE, and two tie rods or stays, AC and BC, united to the beam at its centre, C. A single weight, P, is placed at the centre.

Let Δ_1 be the deflection of the stays, C, C', and Δ_2 the deflection of the beam. Let λ_1 be the coefficient of elongation for the stays and λ_2 for the beam. Let the length of each of each stay be s, the half-span be l and the vertical projection of each stay be v.

1. Deflection of Stays.—The increase of length of each stay is λs. Draw CF at right angles to AC'. Since $\lambda_1 s$ is very small, $AF = AC'$ approximately, and hence $FC' = \lambda_1 s$. We have then by similar triangles

$$\frac{CC'}{FC'} = \frac{s}{r} \text{ or } \frac{\Delta_1}{\lambda_1 s} = \frac{s}{r}$$

From this we obtain

$$\Delta_1 = \lambda_1 \frac{s^2}{r} \qquad (1)$$

Let nP be the portion of the weight carried by the stays. Then $(1-n)P$ is the portion carried by the beam.

Each stay then carries $\frac{nP}{2}$. The strain in each stay is then

$$\frac{nP}{2} \sec.\theta = \frac{nP}{2}\frac{s}{r}.$$

From equation (III), the elongation caused by the strain is

$$\lambda = \frac{S}{F_1 E_1} = \frac{nPs}{2F_1 E_1 r}$$

Inserting this value in (1) we have

$$\Delta_1 = \frac{nPs^3}{2F_1 E_1 r^2} \qquad (2)$$

where $\frac{nP}{2}$ is the weight carried by the stay and E_1 F_1 are the coefficients of elasticity and the area of cross-section of stay.

2. *Deflection of Beam.*—The deflection of a beam, supported at the ends, with a weight, $(1-n)P$, in the middle, is from the theory of flexure $\Delta_2 = \frac{(1-n)Pl^3}{6E_2 I_2}$ where I_2 is the moment of inertia of the cross-section.

If the beam is of rectangular constant cross-section, $I_2 = \frac{1}{12}bh^3$, where b is the breadth and h the height of cross-section. The deflection at the centre is therefore

$$\Delta_2 = \frac{2(1-n)Pl^3}{E_2 F_2 h^2} \qquad (3)$$

where E_2 is the coefficient of elasticity, F_2 the area of cross-section.

Let ρ, Fig. 4, be the radius of curvature of the neutral axis of the beam. Considering the curve of deflection as an arc of a circle, which is approximately true when the unit strain is constant, or when the deflection is small, as is the case in practice, we have $\Delta_2 : l :: l : 2\rho - \Delta_2$, or neglecting Δ_2 as very small in comparison with 2ρ, $\Delta_2 = \frac{l^2}{2\rho}$.

But when Δ_2 is very small, the length of arc is the same as the

length of chord, approximately. The length of the neutral axis, then, is $2l$ and of the lower edge $2l+\lambda_2 2l = 2l(1+\lambda_2)$. Since the lengths are proportional to the radii, $\frac{\rho}{\rho+\frac{h}{2}} = \frac{2l}{2l(1+\lambda_2)}$, or $\rho = \frac{h}{2\lambda_2}$.

Substituting this value of ρ in the value for Δ_2 above, we have

$$\Delta_2 = \frac{\lambda_2 l^2}{h} \tag{4}$$

We have thus found in equations (1) and (4) the deflections in terms of the elongation, and in equations (2) and (3) the deflection in terms of the load.

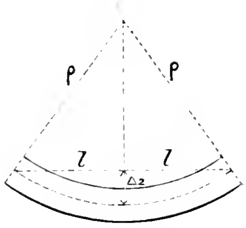

Fig. 4.

We are now ready to apply our principles.

1. To find the best ratio of $\frac{v}{l}$. Since the deflections at C, Fig. 3, must be equal, we can equate equations (1) and (4). We thus have

$$\Delta_1 = \Delta_2 \text{ or } \lambda_1 \frac{s^2}{v} = \lambda_2 \frac{l^2}{h} \text{ or } \frac{v}{h} = \frac{\lambda_1}{\lambda_2}, \frac{s^2}{l^2}. \tag{5}$$

Equation (5) gives then the best ratio of $\frac{v}{l}$, whether the material is the same in both systems or not, if we put for λ_1 and λ_2 their values at the limit of elasticity for each material.

If each system is made of the same material, $\lambda_1 = \lambda_2$ and

$$\frac{v}{h} = \frac{s^2}{l^2} \tag{6}$$

2. To find the load carried by each system.—If we equate (2) and (3) instead of (1) and (4), we have

$$\frac{nPs^3}{2F_1E_1v^2} = \frac{2(1-n)Pl^3}{F_2E_2h^2} \tag{7}$$

From this equation we can easily find n, whether the material in the systems is the same or not.

If, however, the material is the same, we have from (4) and (3)

$\lambda_2 = \frac{2(1-n)Pl}{E_2F_2h}$, and if we put this equal to the value for λ_1, we

have $E_2 = E_1 \cdot \dfrac{2(1-n)Pl}{F_2 h} = \dfrac{nPs}{2F_1 r}$, or if we introduce the best ratio of $\dfrac{r}{h}$ as given by (6)

$$\frac{2(1-n)Pl}{F_2 h} = \frac{nPl^2}{2F_1 sh}, \text{ or } n = \frac{4F_1 s}{F_2 l + 4F_1 s} \qquad (8)$$

The preceding is sufficient to illustrate the use of our equations (I), (II), (III) and the method which must be adopted for any composite structure. We shall now proceed to discuss in a similar manner the structure represented by Fig. 1.

NOTATION.

We group together here the principal notation, which we shall employ, for convenience of reference.

E_1 = coefficient of elasticity of the cable.
E_2 = coefficient of elasticity of the truss.
F_1 = cross-section due to strain at centre of cable.
F_2 = cross-section due to strain at centre of truss.
F_0 = cross-section due to strain at ends of cable.
λ_1 = elongation per unit of length of cable at centre.
λ_2 = elongation per unit of length of truss at centre.
λ = elongation per unit of length of cable at any point.
δ_1 = deflection of cable at any point.
δ_2 = deflection of truss at any point.
Δ_1 = deflection of cable at centre.
Δ_2 = deflection of truss at centre.
I_1 = moment of inertia of cable, I_2 of truss, both at centre.
f_1 = greatest allowable unit strain for cable, f_2 for truss.
s = length of cable supporting dead load only.
t = number of degrees rise or fall above or below mean temperature.
ε = elongation per unit of length due to a rise of temperature of one degree.
q = unit load due to rise or fall of temperature.
h = depth. $2l$ = span. v = versine of cable.
r = height of towers. p = permanent or dead unit load.
m = moving or live unit load.
M_x = moment at any point.

S_x = shear at any point.
M_1 = moment at left end of truss.
M_2 = moment at right end of truss.
H = horizontal pull of cable.
V_1 = vertical reaction of cable at left.

Equilibrium Curve.—Horizontal Force Constant.

The curve or polygon which a perfectly flexible string, hung from two fixed points, assumes when acted upon by a given distributed load or by given concentrated loads, is called the "equilibrium curve" or polygon.

In Fig. 5, let A and B be the ends of the string. In order that these ends may be fixed, we must have at A and B the upward forces V_1 and V_2. The sum of these upward forces must equal the sum of the downward forces. Also if A and B are on the same level, the moment of V_1 with reference to B must be equal and opposite to the sum of the moments of the downward forces with reference to B.

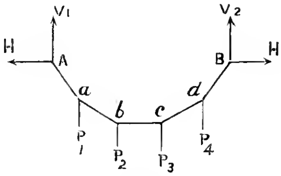

Fig. 5.

So also for V_2 with reference to A. If the forces P_1, P_2, etc., are known and their points of application given, we can then easily find V_1 and V_2. But in order that A may be fixed, we must have not only the upward force, V_1, which can be found as above, but also a horizontal force, H, equal and opposite to the horizontal pull of the string at that point.

The portion of the string Aa must then lie in the direction of the resultant of H and V_1, and the tension in Aa must be equal to that resultant.

The portion ab must then lie in the direction of the resultant of Aa and P_1 and the tension in it is equal to that resultant. But the resultant of P_1 and Aa is the same as the resultant of H, V_1 and P_1. In like manner the tension in any portion, as bc, is the resultant of all the forces to the left or right of that portion.

But all these forces are parallel and vertical, except H, which is horizontal. The tension of any portion, as bc, then, is the resultant of $V_1—P_1—P_2$ and H.

But $V_1—P_1—P_2$ is the shear just to the right of b. Therefore, at any point of an equilibrium curve or polygon, *the vertical load is the*

shear at that point and the horizontal force at every point is constant and equal to the horizontal pull at A or B.

As the loads are more numerous, the polygon approaches a curve. When the load is distributed, we have an equilibrium curve, Fig. 6. The tension in any element of this curve at any point, as ds, is then the resultant of the shear, S, at this point and H, and its direction is the direction of this resultant. We have, then, from similar triangles, completing the parallelogram on H and S,

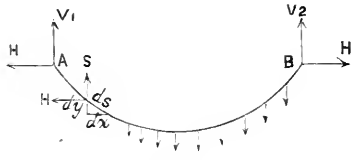

Fig. 6.

$$\frac{dx}{dy} = \frac{H}{S} \tag{9}$$

That is, the tangent of the angle which the tangent to the curve at any point makes with the horizontal, is equal to H divided by the shear at that point.

Equilibrium Curve for Uniform Load a Parabola.

Let the distributed load be uniform and equal to p per unit of length. Let the span be $2l$ and the versine at the centre be v. Then since the load is uniform, it is evident that V_1 must equal V_2 and, whatever the form of the curve, each half must be symmetrical. That is, the lowest point of the curve is at the centre, and at this point $\frac{dy}{dx} = 0$.

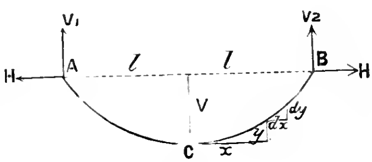

Fig. 7.

Take C as an origin. Then from (9) we have for the vertical force, S, at any point, $S = H\frac{dy}{dx}$. Fig. 7.

The elementary load at any point is then $\frac{dS}{dx} = H\frac{d^2y}{dx^2} = p$.

Integrating this, we have $H\frac{dy}{dx} = px + C$.

Since for $x = 0$, $\frac{dy}{dx} = 0$, the constant $C = 0$ and $H\frac{dy}{dx} = px$.

Integrating again, we have $Hy = \frac{px^2}{2} + C$.

Since for $x = l$, $y = v$, we have $C = Hv - \frac{pl^2}{2}$ and

$$Hy = \frac{px^2}{2} + Hv - \frac{pl^2}{2}.$$

But taking moments about B, we have for the equilibrium of the half BC, since the vertical force at C is zero,

$$Hv = pl \times \frac{l}{2} = \frac{pl^2}{2}$$

Substituting, we have

$$y = v\frac{x^2}{l^2}, \tag{10}$$

which is the equation of a parabola.

Hence, *the curve of a flexible string uniformly loaded is a parabola; and inversely, if a flexible string has the form of a parobola, it must be uniformly loaded.*

Deflection of Cable.—Uniform Live Load Over Entire Span.

Now in the system shown in Fig. 1, the cable carries the entire dead load of the truss, as the suspenders are supposed to be so adjusted during erection, that the unloaded truss just bears at the ends upon the abutments. The weight of truss, flooring, suspenders, etc., may be taken as very nearly uniform, as the variation of weight due to variation of cross-section of flanges and braces can be neglected as very small compared to the uniform dead weight of flooring, wind-bracing, etc. Moreover this uniform load is very great compared to weight of cables. The curve of the cables under the action of the dead load alone may be then considered as very closely a parabola and therefore given by equation (10).

Differentiating, we have $\frac{dy}{dx} = \frac{2vx}{l^2}$.

If the length of arc is s, we have

$$ds = \sqrt{ds^2 + dy^2} = dx\sqrt{1 + \left(\frac{dy}{dx}\right)^2}.$$

Inserting the value for $\frac{dy}{dx}$

$$ds = dx\sqrt{1 + \frac{4r^2x^2}{l^2}} = dx\left(1 + \frac{2r^2x^2}{l^4} - \frac{2r^4x^4}{l^8} - \ldots\ldots\right)$$

If the ratio $\frac{r}{l}$ is small, as is the case for long spans, we can neglect $\frac{r^4}{l^8}$, and have approximately

$$ds = dx\left(1 + \frac{2r^2x^2}{l^4}\right) \tag{11}$$

Integrating between the limits $-l$ and $+l$, we have for the length of the cable when only the dead load acts,

$$s = 2l\left(1 + \frac{2r^2}{3l^2}\right) \tag{12}$$

Equation (12) gives the original length of cable, when the span and versine are given, and the ratio of $\frac{r}{l}$ is small. That is, for long spans.

Now let the entire span be covered from end to end with the uniformly distributed live load. It is required to find the deflection of the cable.

The new curve will evidently also be a parabola of the same span, whose new length s_1 will be $s_1 = 2l\left(1 + \frac{2r_1^2}{3l^2}\right)$ where r_1 is the new versine.

Let λ be the elongation per unit of length at any point caused by the live load acting over the whole span. Now the cable may be composed of links and pins, or of wire. The last is more common. In the first case, the cross-section may be varied according to the strain. The unit strain will then be constant and λ will be constant. In the second case, the cross-section of the cable is constant and equal at any point to the cross-section required by the greatest strain, that is to the cross-section at the ends. The unit strain will then vary as the secant of the angle of inclination, and λ will vary as the unit strain.

Let then λ_1 be the elongation per unit of length at the centre C, Fig. 7. If the cable is composed of links and pins, λ_1 will be constant at every point. If the cable is of wire and of constant cross-section, the elongation per unit of length will be $\lambda_1\frac{ds}{dx}$.

From (11) we have then the elongation at any point

$$\lambda = \lambda_1\left(1 + \frac{2r^2x^2}{l^4}\right) \tag{13}$$

We shall find the deflection of the cable for these two cases separately.

1. When λ_1 is constant, or the cross-section of cable varies so that the unit strain is constant.

In this case, the new length of the chain cable will be

$$s+\lambda_1 s = 2l\left(1+\frac{2v_1^2}{3l^2}\right) \text{ or from (12)}$$

$$2l\left(1+\frac{2v^2}{3l^2}\right)(1+\lambda_1) = 2l\left(1+\frac{2v_1^2}{3l^2}\right).$$

From this equation we can find the new versine v_1. Thus

$$v_1 = v\sqrt{1+\lambda_1\left(1+\frac{3l^2}{2v^2}\right)} = v\left[1+\frac{\lambda_1}{2}\left(1+\frac{3l^2}{2v^2}\right)-\frac{\lambda_1^2}{8}\left(1+\frac{3l^2}{2v^2}\right)^2+\ldots\right]$$

Since λ_1 is a small fraction, this becomes approximately

$$v_1 = v\left[1+\frac{\lambda_1}{2}\left(1+\frac{3l^2}{2v^2}\right)\right] \qquad (14)$$

The distance of any point of the cable below the horizontal AB, Fig. 7, is $v-y = v-\frac{vx^2}{l^2}$, where x is the distance of the point right or left of the centre. The distance of the same point of the deflected cable below the horizontal is $v_1-\frac{v_1x^2}{l^2}$.

The difference of these two distances is the deflection at any point, or $\delta_1 = v_1-v-\frac{x^2}{l^2}(v_1-v)$.

But from (14) $v_1-v = \frac{\lambda_1 v}{2}\left(1+\frac{3l^2}{2v^2}\right) = \frac{3}{4}\lambda_1\frac{l^2}{v}\left(1+\frac{2v^2}{3l^2}\right)$ or, since $\frac{v}{l}$ is small for long spans $v_1-v = \frac{3}{4}\lambda_1\frac{l^2}{v}$.

Hence,

$$\delta_1 = \frac{3\lambda_1}{4v}(l^2-x^2) \qquad (15)$$

where x is the distance of any point right or left of the centre.

For the deflection at the centre, $x=o$ and

$$\Delta_1 = \frac{3\lambda_1 l^2}{4v} \qquad (16)$$

where λ_1 is constant and is the elongation per unit of length due to the strain at the centre caused by the uniform live load when it covers the whole span.

Let the uniform live load be m per unit of length. Then the vertical reactions at the end, Fig. 7, are $V_1 = V_2 = ml$. Taking moments about the centre, we have $Hv_1 = ml \times \frac{l}{2}$ or $H = \frac{ml^2}{2v_1}$ where v_1 is the new versine of the elongated cable. The value of this new versine can be found from (14).

H is the tension at the centre of the cable. If we denote the constant unit strain by f_1 we have from (III)

$$\lambda_1 = \frac{f_1}{E_1} = \frac{H}{F_1 E_1} = \frac{ml^2}{2E_1 F_1 v_1} \tag{17}$$

Equation (15) then becomes

$$\delta_1 = \frac{3ml^2}{8E_1 F_1 v_1 v}(l^2 - x^2) \tag{18}$$

and hence the deflection at the centre of the cable is

$$\Delta_1 = \frac{3ml^4}{8E_1 F_1 v_1 v} \tag{19}$$

where F_1 is the cross-section at the centre of the cable required by the strain at that point, and v_1 is given by the equation

$$v_1 = v\left[1 + \frac{f_1}{2E_1}\left(1 + \frac{3l^2}{2v^2}\right)\right] \tag{20}$$

2. *When the Cross-Section of Cable is Constant.*—In this case the elongation at any point is from (13) $\lambda = \lambda_1\left(1 - \frac{2v^2x^2}{l^4}\right)$.

The elongation of any element ds of the curve is λds, and the new length of the element is $ds + \lambda ds = ds_1$.

From (11) then, we have

$$ds(1+\lambda) = ds_1 = dx\left(1 + \frac{2v^2x^2}{l^4} + \lambda_1 + \frac{4v^2\lambda_1 x^2}{l^4} + \frac{4v^4\lambda_1 x^4}{l^8}\right).$$

Integrating between $-l$ and $+l$

$$s_1 = 2l(1+\lambda_1)\left(1 + \frac{2v^2}{3l^2} + \frac{2v^2\lambda_1}{3l^2(1+\lambda_1)}\right).$$

Since $\frac{v}{l}$ is a small fraction, and $\frac{\lambda_1}{1+\lambda_1} = \frac{1}{1+\frac{1}{\lambda}}$ is also a very small fraction, we have approximately

$$s_1 = 2l(1+\lambda_1)\left(1 + \frac{2v^2}{3l^2}\right).$$

This is apparently the same length as in the first case. But it must

be remembered that λ_1 or the elongation due to the strain at the centre is now less than before, because the cross-section there is greater, and equal to the cross-section at the ends. Let the cross-section at the ends be F_0. Then, since the cross-section is constant,

$$\lambda_1 = \frac{H}{F_0 E_1} = \frac{ml^2}{2E_1 F_0 v_1}.$$

We have then from (15) for the deflection at any point,

$$\delta_1 = \frac{3ml^2}{8E_1 F_0 v_1 v}(l^2 - x^2) \tag{18a}$$

$$\Delta_1 = \frac{3ml^4}{8E_1 F_0 v_1 v} \tag{19a}$$

where we must put for F_0 the cross-section required by the strain at the ends of the cable. Equation (20) gives, as before, the value of v_1.

In *either case*, then, the deflection at any point is

$$\delta_1 = \frac{3ml^2}{8E_1 F v_1 v}(l^2 - x^2) \tag{IV}$$

If we remember that in the first case F is the cross-section F_0 due to the *strain at the centre*, and in the second case F is the cross-section F_0 due to the strain *at the ends*.

The second case is the most common, as a wire cable is more economical than a chain, and such a cable must have a uniform cross-section. We shall suppose in what follows, therefore, a wire cable of constant cross-section, and therefore $F = F_0$. If the formulæ for the first case are required, we have only to replace F_0 by F_1.

(To be continued.)

Improved Drummond Light.—A Russian naval officer, M. de Robinsky, has improved the lime burners of the Drummond light so as to render them much more refractory, and provided some methods for equalizing the temperature in the different portions, so that a single crayon will last about fifteen days in almost constant service. He proposed to prepare oxygen by the permanganate of potash method, or by a new method which he is now studying, and to supply it to houses, condensed in receivers. Tissandier represents the light as very steady and satisfactory, but he is unable to express any opinion as to its economy.—*La Nature.* C.

STEAMSHIP PERFORMANCE.

By John W. Nystrom.

The valuable article written by Chief Engineer Isherwood on the performance of the U. S. steamer *Dispatch*, and published in the January number of the Journal, encouraged me to write a similar article to show that the performance of a steamer can be determined beforehand when the drawings of the vessel and machinery are being made.

The various properties of any form and size of a vessel can be treated with correctness by the aid of the parabolic method of constructing ships, and it is here proposed to apply and exemplify that method on the data given by Chief Engineer Isherwood for the *Dispatch*, for the purpose of comparison, and to render the subject more intelligible.

The principal dimensions of the *Dispatch* are as follows:

L = 174 feet, length of the vessel.

B = 25·5 feet, extreme breadth.

d = 12 feet, mean draught of water.

$\mathfrak{X}$ = 186·58 square feet, area of the greatest cross-section of displacement.

a = 3163·34 square feet, area of the load water line.

D = 19328·64 cubic feet, displacement at 12 feet draught.

0·7138 = ratio of $\mathfrak{X}$ to the surrounding parallelogram.

0·7129 = ratio of **a** to the surrounding parallelogram.

0·5945 = ratio of D to $\mathfrak{X}$ L.

0·4250 = ratio of D to the surrounding parallelopipedon.

From these data we find that the exponent for $\mathfrak{X}$ is $n = 2\frac{1}{2}$, which corresponding cross-section is illustrated on Plate VIII, Nystrom's Pocket Book, and the ordinates for that section are obtained from Table I, page 450, where the correct ratio 0·7142 is found in column **a** $\mathfrak{X}$ D, opposite the exponent $n = 2\frac{1}{2}$.

The exponent for the displacement is $n = 2\frac{1}{2}$, and power $q = 2$, which make the ratio for $D = 0{\cdot}7138 \times 0{\cdot}5952 = 0{\cdot}4248$, which Chief Engineer Isherwood says is 0·4250.

The number 0·5952 is the ratio of D to ⊠ L, and found in column **a** ⊠ D, Table V, page 451, opposite the exponent $n = 2\frac{1}{2}$.

Chief Engineer Isherwood says this ratio is 0·5945.

The centre of gravity of the displacement under the load water line is given to be 7·345 feet, which is evidently wrong, but which can be corrected by formula 4, page 449, N. P. B., namely, as follows:

$$e = \frac{12}{2\left(2 - \dfrac{19328{\cdot}64}{3163{\cdot}34 \times 12}\right)} = 4{\cdot}0246 \text{ feet, instead of } 7{\cdot}345 \text{ feet.}$$

This formula does not include the displacement of the keels, which lowers the centre of gravity about half an inch in that form and size of displacement.

It now remains to determine the performance of the vessel in motion, that is, the resistance in water, which is equal to the thrust of the propeller, and found by formula 16, page 449, N. P. B. For this formula, it is necessary to find the mean angle of resistance and wet area of the displacement, namely, as follows:

Suppose the section ⊠ is located at $l' = 109$ feet from the stem, and $l = 65$ feet from the sternpost, then the mean angles of entrance in the bow and delivery in the stern are found by the formulas 17 and 18, page 449, N. P. B., for which the factor t is found in the column *Res. t,* opposite the exponent of the displacement in the tables. In the case before us we have given the exponent of the displacement $n = 2{\cdot}5$, and power $q = 2$, by which we find the tangent $t = 1{\cdot}355$, Table V, page 451.

During the trial, Jan. 14, 1880, the *Dispatch* drew $d = 12{\cdot}2$ feet, making the cross-section ⊠ $= 195{\cdot}55$, including the sections of the two bilge keels, 4·8 square feet. The cross-section for determining the mean angle of resistance, and wet area of the hull, will then be ⊠ $= 195{\cdot}55 - 4{\cdot}8 = 190{\cdot}35$ square feet. The area of the load water line during the trial was **a** $= 3180$ square feet.

Now we have all the data necessary for calculating the mean angle of resistance, namely, as follows:

Formula 17, page 449. $\quad \text{Tan.}x = \dfrac{190{\cdot}35 \times 1{\cdot}335}{109 \times 12{\cdot}2} = 0{\cdot}1911.$

Mean angle of resistance, 10° 50′. $\quad \text{Sin.}x = 0{\cdot}18795. \quad \sqrt{0{\cdot}18795^3} = 0{\cdot}081483.$

Formula 18, page 449. $\quad \text{Tan.}y = \dfrac{190{\cdot}35 \times 1{\cdot}335}{65 \times 12{\cdot}2} = 0{\cdot}32045.$

Mean angle of delivery, 17° 46′. Sin. $V = 0{\cdot}30514$. $\sqrt{0{\cdot}30514^3} = 0{\cdot}16856$.

The fractions 0·081483 and 0·16856 are the radicals in the formula 16, page 449, namely, as follows: Resistance

$$R = 2{\cdot}858\ M^2 \left[\aleph \left(0{\cdot}9 \sqrt{\sin.^3 v} + 0{\cdot}1 \sqrt{\sin.^3 V} \right) + \frac{A\ k}{\sqrt[4]{L}} \right]$$

M = nautical miles per hour, A = wet area of displacement and k = friction coefficient, to be found on page 448, for different conditions of the hull or wet surface of the vessel.

The wet area of the displacement is found by the formula,

$$A = [\mathbf{a} + 2\,(\aleph + d\ L)] \sqrt{\frac{D}{BLd}}$$

The factor under the radical is the ratio 0·4248 of the displacement, and the wet area will be as follows:

$A = [3180 + 2(190{\cdot}35 + 12{\cdot}2 \times 174)] \sqrt{0{\cdot}4248} = 5087{\cdot}9$ square feet.

This wet area includes only a part of that of the central keel, but not that of the bilge keels, which Chief Engineer Isherwood says are 416 square feet, to which add 96 square feet for the remainder of the central keel, makes the friction area $A = 5600$ square feet.

The hull of the *Dispatch* was coppered, for which the coefficient of friction is 0·0045. See page 448, N. P. B.

The speed of the vessel on trial was $M = 10{\cdot}75$ nautical miles per hour. Now we have all the data necessary for finding the resistance of the vessel by the above formula 16.

$$R = 2{\cdot}858\ M^2 \left[195{\cdot}55 \left(0{\cdot}9 \times 0{\cdot}081483 + 0{\cdot}1 \times 0{\cdot}16856 \right) + \frac{5600 \times 0{\cdot}0045}{\sqrt[4]{174}} \right] = 8117{\cdot}1 \text{ pounds.}$$

That is, the thrust of the propeller should be 8117·1 pounds. Chief Engineer Isherwood makes the resistance 8146·33 pounds, or only 29·23 pounds more than by my formula. I am convinced that the formula gives the true resistance if supplied with correct data.

The term $\aleph\,(0{\cdot}9 \sqrt{\sin.^3 v} + 0{\cdot}1 \sqrt{\sin.^3 V})$ represents the resistance to the vessel in motion, which in the case before us is 17·637, of which $0{\cdot}9 \sqrt{\sin.^3 v}$ represents the forebody and $0{\cdot}1 \sqrt{\sin.^3 V}$ the after body

of the displacement. The second term $\frac{A\ k}{\sqrt[4]{L}}$, represents the friction of the wet surface, which in this case is 6·94. The sum of these terms is 24·577, which represents the total resistance. That is, the resistance in displacing the water while the vessel is in motion is 71·762 per cent., and the friction 28·238 per cent. of the gross resistance.

For fuller vessels, the resistance in displacing the water will be much greater in proportion to the friction, but if the vessel is fouled with barnacles the friction may become much greater than the resistance in displacing the water; all of which can be determined by the formula 16 for any form and size of vessel.

Chief Engineer Isherwood says, in the January number of the JOURNAL, pages 25 and 26, that "the entire resistance of the vessel was sensibly that of the water to its immersed external surface; and, consequently, no engine power was expended in overcoming the resistance of the water to displacement by the progress of the vessel. That is to say, the difference between the power exerted by the fore body of the vessel in raising the displaced water from the centre of gravity of the greatest immersed transverse section of the vessel to the general water level, and the power exerted upon the after body of the vessel in the direction of its motion by the ascending column of water caused by the forward movement of the vessel, were sensibly equal," etc.

These ideas conflict with the science of hydraulics.

The horse-power required for friction in the moving of a surface in water is found in the following way:

S = speed or velocity, in feet per second, of the surface through water.

M = nautical miles per hour of the same surface.

k = coefficient of friction, or the force, in pounds, required to move one square foot friction surface with a velocity of one foot per second.

A = friction surface, in square feet.

L = length of the friction surface in the direction of motion.

F = force, in pounds, required to move that surface.

$$F = \frac{AS^2k}{\sqrt[4]{L}}, \text{ of which the horse-power is } H' = \frac{A\ S^3\ k}{550\ \sqrt[4]{L}}$$

When the velocity is expressed in nautical miles, of 6086 feet each, the force and horse-power will be

$$F = \frac{6086^2\ A\ M^2\ k}{(60 \times 60)^2 \sqrt[4]{L}} = \frac{10288{\cdot}7\ A\ M^2\ k}{\sqrt[4]{L}}$$

$$\text{HP} = \left(\frac{6086}{60 \times 60}\right)^3 \frac{A\ M^3\ k}{550\ \sqrt[4]{L}} = \frac{A\ M^3\ k}{113{\cdot}935\ \sqrt[4]{L}}$$

Example.—Required the horse-power of a smooth copper surface, $A = 5698$ square feet, for which $k = 0{\cdot}0045$, moving with a speed of $M = 10{\cdot}75$ nautical miles per hour, when the length $L = 174$ feet.

$$\text{HP} = \frac{5600 \times 10{\cdot}75^3 \times 0{\cdot}0045}{113{\cdot}935 \times \sqrt[4]{174}} = 75{\cdot}653 \text{ horse-power.}$$

Chief Engineer Isherwood says 266 horse-power.

The horse-power required for propelling the steamer *Dispatch* at a speed of $M = 10{\cdot}75$ nautical miles per hour, with the resistance given by the formula 16, should be

$$\text{HP} = \frac{6086\ M\ R}{60 \times 33000} = \frac{10{\cdot}75 \times 8117{\cdot}1}{325{\cdot}337} = 268{\cdot}21 \text{ horse-power.}$$

Chief Engineer Isherwood says 269·17 horse-power.

The horse-power consumed by friction of the water against the propeller blades is found by the following formula:

$$\text{HP} = \frac{k\ \mathbf{R}\ L\ N\ n^3}{59400000\ P}(311{\cdot}71\ \mathbf{R}^4 + 26{\cdot}319\ \mathbf{R}^2\ P^2 + P^4)$$

See Nystrom's "Elements of Mechanics," pages 178 to 181 inclusive, for explanation how this formula is obtained.

For the propeller of the steamer *Dispatch* we have given $\mathbf{R} = 5{\cdot}55$ feet radius; $L = 1{\cdot}4583$, the length in the direction of its axis; $P = 19{\cdot}9$ feet pitch; $N = 4$ blades; $n = 64{\cdot}533$ revolutions per minute; $k =$ friction coefficient, which for smooth finished brass is 0·0045. The friction horse-power will then be

$$\text{HP} = \frac{0{\cdot}0045 \times 5{\cdot}55 \times 1{\cdot}4583 \times 4 \times 64{\cdot}5333^3}{59{,}400{,}000 \times 19{\cdot}9}(311{\cdot}71 \times 5{\cdot}55^4 + 26{\cdot}319$$
$$\times 5{\cdot}55^2 \times 19{\cdot}9^2 + 19{\cdot}9^4) = 26{\cdot}73 \text{ horse-power.}$$

Chief Engineer Isherwood gives the friction horse-power to be 25·62, with the friction $k = 0{\cdot}0045$, for which the same formula has probably been used. This savant, I believe, was the first one to appreciate the value of and to determine the friction horse-power of screw propellers, and his first process was very laborious. See JOURNAL OF THE FRANKLIN INSTITUTE, February, 1854, page 121.

To find the horse-power required for driving a vessel a given speed.

For this purpose, like for the resistance, it is necessary to know the shape of the vessel, that is, its exponents, angles of resistance, greatest immersed section, wet area of the hull, etc.

$$\text{Call}\quad [X] = \left[\infty\left(0{\cdot}9 + \sqrt{\sin.^3 v} \quad 0{\cdot}1 + \sqrt{\sin.^3 V}\right) + \frac{A\ k}{\sqrt[3]{L}}\right]$$

This is the factor of resistance, which in the case of the *Dispatch* is $[X] = 24{\cdot}577$.

The horse-power required for driving a vessel of any form and size will be as follows:

$$\text{HP} = \frac{M\ R}{325{\cdot}337} = \frac{2{\cdot}858\ M^3}{325{\cdot}337}\ [X]$$

By eliminating the coefficient 2·858, the formula for horse-power becomes

$$\text{HP} = \frac{M^3}{113{\cdot}82}\ [X]$$

The indicated horse-power of the engine should be about 50 per cent. more for working the pumps and frictions of the engine and propeller.

The speed with which a steamer will run with a given horse-power will be

$$M = \sqrt[3]{\frac{113{\cdot}82\ \text{HP}}{[X]}}$$

The steamer *Dispatch* is constructed very near like the steam propeller represented on Plate X, N. P. B., of which the general formula appears on page 446. A general formula for the *Dispatch* may be set up as follows:

$$\left\{\frac{W\ 2{\cdot}5\times1}{D\ 2{\cdot}5\times2}\right\}65\left(\frac{174\times25\times12}{\infty\ 2{\cdot}5\times1}\right)109\left\{\frac{W\ 2\times1{\cdot}5}{D\ 2{\cdot}5\times2}\right\}$$

Any one who understands the parabolic method can construct a vessel like the *Dispatch* from the above formula, and he can know all the properties of the vessel before a single line of it is laid down for the drawing. The parabolic method enables the shipbuilder to reason with certainty and clearness about forms of ships.

The order of proceedings in the ordinary or old method of constructing ships is as follows:

Some boards are planed up, and put together with wooden pins,

from which a model of the intended shape of the vessel is carved out according to the rule of thumb judgment, and several models are often made before a desired shape is obtained. When the model is finished it is taken apart, and each board is laid on the drawing paper for drawing the corresponding water lines therefrom. After all the water lines are so drawn, the body plan is made therefrom.

From this drawing the lines were laid down on the ship's floor by the aid of scale of measurements. If it is desired to know correctly the properties of the vessel, such as areas of water lines and cross-sections, displacement, centres of gravity, metacentre, etc., calculations are made by the rules of Chapman or Simpson, which is a very laborious process, very seldom carried out, but the shipbuilders rely upon their experience in approximating these data sufficiently near for practical purposes.

With the parabolic method of constructing ships the order of proceedings is the reverse of that of the old method, namely, as follows:

First, set up a formula for the desired shape of the vessel, from which calculate the ordinates, areas of water lines and cross-sections, displacement, centres of gravity metacentre, etc. From the so obtained data lay down the lines on the drawing for the complete vessel. If a model is required make it from the drawing. Then lay down the lines on the ship's floor, not altogether by scale measurements, but from the original calculation, because the scale measurements are not reliable when enlarged from the drawing to the full size of the ship.

The calculations required by the parabolic method is about one-tenth of that by the Chapman's or Simpson's rules.

Transit Observations.—M. Virlet D'Aoust has proposed to M. Dumas, the President of the International Commission upon the Transit of Venus, a plan for preventing the disturbances of irradiation. It consists of an eclipsing disc, or diaphragm, which is connected with clockwork so as to move through the field of the telescope with the same rapidity as the planet. The luminous phenomena being thus withdrawn from the eyes of the observers, he thinks that they could better appreciate the precise moments of contact, so that Halley's method could be practically applied and an approximation of the solar parallax obtained which would be much more satisfactory than was possible at any previous transit.—*Les Mondes.* C.

RADIO-DYNAMICS: ATOMIC PHYLLOTAXY AND KINDRED HARMONIES.

By Pliny Earle Chase, LL.D.

Communicated to the American Philosophical Society, November 4, 1881.

Clarke (*P. Mag.* [5] xii, 109–110) gives the result of his recalculation of atomic weights, which inclines him to look favorably on Prout's hypothesis, although he had previously believed that it had been forever overthrown. Maximilian Gerber (*Les Mondes*, cited in *Chemical News*, xliii, 242–243) rejects the hypothesis, but he gives four additional empirical units, which seem to show that groups of similar valency may have special common divisors. The varied evidences of the phyto-dynamic importance of hydrogen favor Clarke's deliberate opinion, and Gerber's factors may help towards its establishment. The possibility of measuring undulating *vis viva* by orbital areas, as well as by the distance of projection against uniform resistance, gives a clue for reconciling some apparent oppositions of indications.

The phyllotactic law distributes leaves and branches evenly around the stems of vegetables, so that all parts of the plant may share the benefit of heat, air and moisture. In 1849, Dr. Thomas Hill, at the request of Professor Peirce, showed that the times of planetary revolution are phyllotactic (*Proc. Amer. Assoc.*, vol. 2). The planets are, therefore, distributed around the sun so evenly as to avoid the destruction of the system by the accumulated perturbations of its principal masses.

If the several atomic elements have especial systems of ætherial vibrations, we may reasonably look for evidences of a phyllotactic harmony which contributes to the stability of equilibrium in chemical compounds. The following table, which includes about one-half of the known elements, contains multiples of the phyllotactic divisor, $\frac{8}{5}$H or 1·6H, compared with Clarke's recalculation of atomic weights.

	Phyllotactic.	Clarke.	Difference.
O	10 × 1·6 = 16	15·963	·037
Fl	12 × 1·6 = 19·2	18·984	·216
Mg	15 × 1·6 = 24	23·951	·049

	Phyllotactic.	Clarke.	Difference.
S	20 × 1·6 = 32	31·984	·016
Cl	22 × 1·6 = 35·2	35·370	·170
Ca	25 × 1·6 = 40 ·	39·990	·010
Ti	31 × 1·6 = 49·6	49·847	·246
V	32 × 1·6 = 51·2	51·256	·056
Se	49 × 1·6 = 78·4	78·797	·397
Br	50 × 1·6 = 80	79·768	·032
Zr	56 × 1·6 = 89·6	89·367	·234
I	79 × 1·6 = 126·4	126·557	·157
Te	80 × 1·6 = 128	127·960	·040
Cs	83 × 1·6 = 132·8	132·583	·217
Ytter	108 × 1·6 = 172·8	172·761	·039
Bo	7 × 1·6 = 11·2	10·940	·260
Al	17 × 1·6 = 27·2	27·009	·191
Fe	35 × 1·6 = 56	55·913	·087
Ga	43 × 1·6 = 68·8	68·854	·054
Cd	70 × 1·6 = 112	111·770	·230
In	71 × 1·6 = 113·6	113·398	·202
Yt	56 × 1·6 = 89·6	89·816	·216
Ru	65 × 1·6 = 104	104·217	·217
Ro	65 × 1·6 = 104	104·055	·055
Rh	66 × 1·6 = 105·6	105·737	·137
Sb	75 × 1·6 = 120	119·955	·045
Ta	114 × 1·6 = 182·4	182·144	·256
W	115 × 1·6 = 184	183·610	·390
Os	124 × 1·6 = 198·4	198·494	·094
Hg	125 × 1·6 = 200	199·712	·288
Pb	129 × 1·6 = 206·4	206·471	·071
Th	146 × 1·6 = 233·6	233·414	·186
U	149 × 1·6 = 238·4	238·482	·082

The greatest difference in the above table of 33 elements is less than 25 per cent. of the phyllotactic unit. Gerber's longest table for a single divisor contains but 25 elements; his greatest difference is more than 36 per cent. of his empirical divisor. If the eight elements which possess the greatest phyllotactic differences were rejected from this comparison, so as to make the table of the same length as Gerber's, the greatest remaining difference would be less than 15 per cent.

of the divisor. The photo-dynamic approximation is, therefore, much closer than the empirical.

Gerber says that "no single relation exists among" his divisors, therefore they "have no value in themselves." There is, however, a relation he failed to discover, for they also are phyllotactic, as will be seen by the following comparison:

	Gerber.		Phyllotactic.	
H	·9997		H	·998
D_1	·768	$\frac{5}{13} \times$	2H	·768
D_2	1·995		2H	1·996
D_3	1·559	$\frac{5}{2} \times$	$\frac{5}{8}$H	1·559
D_4	1·245	$\frac{5}{2} \times$	$\frac{1}{4}$H	1·247

The first six phyllotactic numbers are 1, 2, 3, 5, 8, 13; the third does not appear in the formation of the theoretical divisors, but the others are all employed. The simple phyllotactic relation of all the divisors to H shows that they *have* "value in themselves." Upon examining their mutual relations, it will be seen that $D_1 = \frac{5}{13}D_2 = 2 \times \frac{2}{5} \times \frac{8}{13}D_3 = \frac{8}{13}D_4$; $D_2 = 2 \times \frac{2}{5} \times \frac{8}{5}D_3 = \frac{8}{5}D_4$; $D_3 = \frac{5}{2} \times \frac{1}{2}D_4$; $D_4 = 1\ \overline{HD_3}$. These varied provisions for the stability of cyclical equilibrium, in all possible varieties of intermolecular ætherial movements, show that the command, "Let there be light," manifested its formative power of organization as soon as material atoms were set in motion.

The appearance of the first five phyllotactic numbers in crystallization, furnishes a step from inorganic to organic morphology, giving new meaning to the landscapes on our frosted window-panes, as well as to the protective mimicry of vegetables and animals, as illustrations of the "distributive ratio" which alike controls light-waves, atomic inertia, crystalline structure, organic growth, planetary configuration and interstellar action.

The importance of oxygen and hydrogen, both in mutual combination and in connection with other elements, suggests the following comparative grouping of Clarke's table of atomic weights:

O = 16; H = 1·0032.		Difference.	O = 16; H	1·0023.	Difference.
Br	79·951	·049	Bi	208·001	·001
I	126·848	·152	Pb	206·946	·054
Mg	24·014	·014	Mn	54·029	·029
Zn	65·054	·054	Fe	56·042	·042
Cs	132·918	·082	Ni	58·062	·062

O = 16; H = 1·0023.		Difference.	O = 16; H = 1·0023.		Difference.
Ag	107·923	·077	Co	59·023	·023
Tl	204·183	·183	Bo	10·966	·034
Se	78·078	·022	Ga	68·963	·037
Mo	95·747	·253	Ce	149·747	·253
W	184·032	·032	Ytte	90·023	·023
U	239·030	·030	Ytter	173·158	·158
P	31·029	·029	La	138·844	·156
Cd	112·027	·027	Di	144·906	·094
Hg	200·171	·171	Th	233·951	·049
Ba	137·007	·007	Pt	194·867	·133
C	12·001	·001	Ir	193·094	·094
Ti	49·961	·039	Os	198·951	·049
Sn	117·968	·032	Pd	105·981	·019
Fl	18·984	·016	Zr	89·367	·367
Cl	35·370	·370	N	14·021	·021
Li	7·007	·007	Sb	115·955	·045
Gl	9·085	·085	Ta	182·144	·144
Na	22·998	·002	Sc	43·980	·020
K	39·019	·019	Al	27·009	·009
Rb	85·251	·251	V	51·256	·256
S	31·984	·016	As	74·918	·082
Te	127·960	·040	Cu	63·173	·173
Cr	52·009	·009	Er	165·891	·109
Ca	39·990	·010	Rh	104·055	·055
Sr	87·374	·374	Ru	194·217	·217
Si	28·195	·195	Au	196·155	·155

The above tables seem to show that, if Prout's law is correct, the value of the oxygen atom has been more accurately determined than that of the hydrogen atom. The deviations of Mo, In, Ce, Cl, Rb, Sr, Zr and V are so great as to require some explanation, which may, perhaps, be found in phyllotactic or harmonic influence, as indicated by the following relations to oxygen:

	Observed.	Phyllotactic.	Difference.
Mo	$95·747 \times \frac{1}{16}$O	$2^5 \times 3 = 96$	·253
In	$113·659 \times$ "	$7 \times 13 \times \frac{5}{4} = 113·75$	·091
Ce	$140·747 \times$ "	$3 \times 61 \times \frac{10}{13} = 140·769$	·022
Cl	$35·451 \times$ "	$2 \times 23 \times \frac{10}{13} = 35·385$	·066
Rb	$85·529 \times$ "	$3 \times 37 \times \frac{10}{13} = 85·385$	·144

	Observed.		Phyllotactic.	Difference.
Sr	87·575 ×	"	$5^2 \times 7 \times \frac{1}{2} =$ 87·5	·075
Zr	89·573 ×	"	$11 \times 13 \times \frac{5}{8} =$ 89·375	·198
V	51·373 ×	"	$2 \times 41 \times \frac{5}{8} =$ 51·25	·123

"Sir W. Thomson is led, from the consideration of various experiments with fluids and solids and the study of smoke rings, to speculate upon elasticity as an evidence of motion. The kinetic theory of gases requires that the molecule or atom shall be elastic. 'But this kinetic theory of matter is a dream and must remain so until it can explain chemical affinity, electricity, magnetism, gravitation and inertia.' The writer looks forward to a greater generalization which shall include elasticity as a form of motion."—J. T., in *Amer. Jour. of Science*, Nov. 1881.

My first physical paper (*Proc. Am. Phil. Soc.*, ix, 283–8) deduced approximate values of solar mass and distance from the combined action of daily rotation, yearly revolution and atmospheric elasticity. All my subsequent radio-dynamic investigations have been based upon the consideration of the various forms of harmonic relation which *ought* to follow from the undulations of an all-pervading elastic medium, such as the luminiferous æther is generally supposed to be.

Schuster (*Proc. Roy. Soc.*, xxxi, 337–47) discusses the probability of accidental harmonic coincidences in spectral wave-lengths, giving the following summary of his results for the iron spectrum:

"*1. There is a real cause acting in a direction opposed to the law of harmonic ratios, so far as fractions formed by numbers smaller than seventy are concerned.*

"*2. After elimination of the first cause, a tendency appears for fractions formed by two lines to cluster round harmonic ratios.*

"*3. Most probably some law hitherto undiscovered exists, which in special cases resolves itself into the law of harmonic ratios.*"

The relations which I have pointed out, between planetary harmonic roots and spectral harmonic quotients, suggest the probability that the opposition to strict harmonic ratios may be due to differences of inertia in the wave-systems, which would be more rigidly harmonic were it not for such differences. The simple tendency of all elastic media to harmonic vibrations would then be the general law, instead of a law which becomes harmonic "in special cases."

In waves which are propagated with such rapidity as those of light it seems reasonable to suppose that there may be large harmonic fac-

tors, which are modified by smaller disturbing influences. Schuster's analysis does not reach my own harmonic comparisons. In the investigation which was suggested by Dr. Henry Draper I found 11 harmonic divisors with a common cosmical factor, which deviate from the observed divisors by a mean amount of less than $\frac{1}{19}$ of one per cent. The greatest difference is in the C line, where the theoretical harmonic divisor is 1·1530, the observed divisor being 1·1592, giving a deviation of $\frac{31}{58}$ of one per cent. The greatest difference between either of my harmonic lines and the corresponding "basic line" is $\frac{1}{3}$ of one per cent. In my harmonic relations of the corona line the greatest discrepancy is $\frac{1}{20}$ of one per cent; in those of the hydrogen lines $\frac{1}{14}$ of one per cent.

Liveing and Dewar (*Proc. Roy. Soc.*, xxxii, 189–203) give some results of their investigations on the spectrum of magnesium, which seem to strengthen the probability of large harmonic factors, modified by small disturbances. The only two single lines which are found in the flame-, arc- and spark-spectra have wave-lengths of 2850 and 4570, respectively. These represent, with close approximation, the phyllotactic numbers 5 and 8, viz.:

Phyllotactic.	Observed.
2854	2850
4566	4570

The phyllotactic ratio $\frac{5}{8}$ also appears between the limiting lines of the hydrogen spectrum C and *h*.

In the arc- and spark spectra there is "a very striking group of two very strong lines at wave-lengths about 2801 and 2794" (*loc. cit.*, p. 201), and "one line common to the arc and spark at wave-length 4703" (*Ib.*, p. 203), which does not appear in Angstrom's table." The difference, 7, between the "two very strong lines" has modified the other lines, as is shown below:

Harmonic.	Observed.
$7 \times 399 = 2793$	2794
$7 \times 400 = 2800$	2804
$7 \times 407 = 2849$	2850
$7 \times 653 = 4571$	4570
$7 \times 672 = 4704$	4703

The greatest discrepancy is $\frac{4}{7}$ of the harmonic unit, the mean difference being only $\frac{1}{35}$ of the unit. If there were no law controlling the

approximations, the probable maximum difference would be ·5 of the unit, and the mean difference would be ·25 of the unit.

It seems reasonable to look for stronger evidence of undisturbed or slightly modified harmonic influence in hydrogen than in any of the heavier elements. Accordingly, Professor Johnstone Stoney has "shown that three out of the four lines in the visible part of the spectrum have wave-lengths which, to a high degree of accuracy, are in the ratio of 20:27:32." I find, moreover, that three of the lines are in simple geometric ratio, as will be seen by the following comparisons:

Theoretic Harmonic Lines.	Observed.
$\alpha = (2 \times 3)^3 \times 30{\cdot}379 = 6562{\cdot}8$	6561·8
$\beta = 5 \times 2^5 \times 30{\cdot}379 = 4860{\cdot}6$	4860·6
$\gamma = (\delta^2 \beta)^{\frac{1}{3}} = 4340{\cdot}1$	4340·
$\delta = 5 \times 3^3 \times 30{\cdot}379 = 4101{\cdot}1$	4101·2

The extreme lines are phyllotactic, δ being $\frac{5}{8}$ of α. The greatest discrepancy is $\frac{1}{410}$ of one per cent., which is so far within the limits of probable error as to furnish ground for the following examination of Schuster's criteria.

1. The ratio between the hydrogen lines α and δ is between $\frac{6}{5}$ and $\frac{3}{2}$.

$\alpha \div \delta = a =$	1·59997
$8 \div 5 = b =$	1·60000
$3 \div 2 = c =$	1·50000
$b - c = d =$	·10000
$b - a = e =$	·00003

$e \div d = \frac{3}{10000000}$, or less than $\frac{1}{83}$ of one per cent. of the probable error.

2. The ratio between γ and δ is between $\frac{91}{86}$ and $\frac{18}{17}$.

$\gamma \div \delta = a_1 =$	1·058227
$18 \div 17 = b_1 =$	1·058824
$91 \div 86 = c_1 =$	1·058140
$b_1 - c_1 = d_1 =$	·000684
$a_1 - c_1 = e_1 =$	·000087

$e_1 \div d_1 = \frac{29}{228}$, the probable error being $\pm \frac{57}{228}$.

3. The ratio between α and β is between $\frac{27}{20}$ and $\frac{77}{57}$.

$\alpha \div \beta = a_2 =$	1·350165
$77 \div 57 = b_2 =$	1·350877
$27 \div 20 = c_2 =$	1·350000
$b_2 - c_2 = d_2 =$	·000879
$a_2 - c_2 = e_2 =$	·000165

$e_2 \div d_2 = \frac{165}{877}$, the probable error being $\pm \frac{219}{877}$.

If we were to end our comparisons at this point we might pronounce the test entirely satisfactory, and the evidence of harmonic influences, in which all the lines are involved, would be deemed conclusive. But if we try another mode of grouping we reach a different result.

4. The ratio between β and δ is between $\frac{32}{27}$ and $\frac{77}{65}$.

$$\begin{array}{rcll}
\beta \div \delta & = a_3 = & & 1{\cdot}185018 \\
77 \div 65 & = b_3 = & & 1{\cdot}184616 \\
32 \div 27 & = c_3 = & & 1{\cdot}188185 \\
c_3 - b_3 & = d_3 = & & {\cdot}000569 \\
c_3 - a_3 & = e_3 = & & {\cdot}000166
\end{array}$$

$e_3 \div d_3 = \frac{166}{569}$, the probable error being only $\frac{142}{569}$. Therefore the test fails to discover any harmonic influence in this case.

5. The ratio between β and γ is between $\frac{28}{25}$ and $\frac{75}{67}$.

$$\begin{array}{rcll}
\beta \div \gamma & = a_4 = & & 1{\cdot}119816 \\
28 \div 25 & = b_4 = & & 1{\cdot}120000 \\
75 \div 67 & = c_4 = & & 1{\cdot}119403 \\
b_4 - c_4 & = d_4 = & & {\cdot}000507 \\
b_4 - a_4 & = e_4 = & & {\cdot}000184
\end{array}$$

$e_4 \div d_4 = \frac{184}{597}$, the probable error being only $\pm \frac{149}{597}$. Therefore the test fails in this case also.

6. The ratio between α and γ is between $\frac{62}{41}$ and $\frac{65}{43}$.

$$\begin{array}{rcll}
\alpha \div \gamma & = a_5 = & & 1{\cdot}511936 \\
62 \div 41 & = b_5 = & & 1{\cdot}512195 \\
65 \div 43 & = c_5 = & & 1{\cdot}511698 \\
b_5 - c_5 & = d_5 = & & {\cdot}000567 \\
b_5 - a_5 & = e_5 = & & {\cdot}000259
\end{array}$$

$e_5 \div d_5 = \frac{37}{81}$, the probable error being only $\pm \frac{20}{81}$. The test, therefore, fails again, the number of failures in the whole comparison being exactly equal to the number of confirmations. Hence it is evident that Schuster's criterion is insufficient, at least when the probable errors of observation are not satisfactorily ascertained. Even when they are known, the proper application of the test will often require supplementary calculations of such intricacy as to make it practically inoperative.

By increasing the magnitude of the harmonic ratios the test may sometimes be made to indicate a probability, which really exists, but which is not shown by Schuster's method. For example, $\beta \div \gamma$ is between $\frac{6}{5}$ and $\frac{7}{6}$. These values give $d_4 = {\cdot}033333$; $e_4 = {\cdot}000184$; $e_4 \div d_4 = \frac{134}{33333}$, which is less than $\frac{1}{45}$ of the probable error. In like manner, $\alpha \div \gamma$ is between $\frac{3}{2}$ and $\frac{4}{3}$. These values give $d_5 = {\cdot}166667$; $e_5 = {\cdot}011936$; $e_5 \div d_5 = \frac{1119}{15625}$, which is less than $\frac{4}{13}$ of

the probable error. These results seem to indicate the propriety of harmonic comparisons between terms which are unquestionably of the same order of magnitude. Thus, in Schuster's calculation (*loc. cit.*, p. 338), the ratio ·96476 lies between $\frac{55}{57}$ and $\frac{55}{58}$, the difference between these two fractions being ·016636. The difference of the fraction in the sodium spectrum from the nearest of the comparative fractions is ·000152, which is only ·00914 of the difference between the fractions themselves, or less than $\frac{1}{27}$ of the probable error.

If a supposed harmonic relation can be represented by a fraction with terms of a single digit, Schuster's test might fail even with the above modification, provided the probable error of observation should be greater than $\frac{1}{4} \times \frac{1}{8} \times \frac{1}{9}$; if the terms are of two digits it would not be trustworthy if the probable error were greater than $\frac{1}{4} \times \frac{1}{98} \times \frac{1}{99}$. If the modifications of *vis viva* in synchronous wave-systems are of the same order of magnitude as the variations of planetary eccentricity, the limit of probable error would be at least $\frac{1}{3}$, instead of $\frac{1}{4}$ of the difference between adjacent fractions which have a common numerator. This would be the case for each of the compared pairs of wave-lengths, the probability for the entire system being equivalent to the product of the independent probabilities.

All estimates of abstract probability, in such cases, should be greatly increased by the mathematical necessity that synchronous undulations in elastic media *must be* harmonic. In view of this consideration, the indications of a harmonic tendency pervading an entire system, such as I have pointed out in many of my own comparisons, are far more significant than conclusions which can be drawn from restricted investigations.

Whatever tests may be applied, it should always be remembered that the failure to discover a harmonic influence between any two given lines does not affect, in the slightest degree, the evidence of harmonic influence between other lines. The failing cases are entitled to no weight in drawing the final conclusion. We should, therefore, have been fully justified in stopping our examination of the observed lines in the hydrogen spectrum as soon as we found that α is harmonically connected with β and δ, and that γ is similarly connected with δ. Even if subsequent discussion had failed to show any probable evidence of harmony between β and γ, β and δ, α and γ, the fact that there are such harmonies, operating through the relations of the intermediate to the extreme wave-lengths, would have been unshaken.

A New Seaport.—It has been proposed in Germany to dredge the Rhine, so that Cologne may become a seaport. The proposition has been received with much favor and with some apprehension upon the part of the Hollanders and Netherlanders, through fear of serious injury to the ports of Antwerp and Rotterdam.—*Chron. Indust.* C.

Tunnel through the Pyrenees.—Louis XIV, when sending his grandson to reign over the Spaniards, said: "There are no more Pyrenees." The Spaniards propose to give a new meaning to his boast by tunneling the mountains, in order to remove the obstacle which they oppose to commercial relations with France. A bill has already been presented to the Cortes for authorizing the undertaking. The expenses are to be borne by the two countries. The tunnel would shorten the distance between Madrid and Paris about 100 kilometres (62·14 miles).—*Chron. Indust.* C.

Columnar Lightning.—Prof. F. Mandoj, of Albano, describes a meteorological phenomenon which he observed at Noci, a village between the Adriatic and the Gulf of Tarentum. The sky, which had been clear the whole morning, with a cool and pleasant breeze, began to darken soon after noon, with clouds indicating a storm from the south. About 4 o'clock other clouds came rapidly from the northwest, from which a gentle rain fell. The south wind soon increased, driving its clouds before it and accompanied by a violent rain and numerous terrible peals of thunder. When the clouds from the south passed those from the northwest the flashes passed between the strata of cloud so rapidly and yet so silently as to produce the appearance of majestic columns of light, lasting in some cases as much as 7 seconds. Prof. Mandoj supposes that the two clouds were charged with electricity of the same kind, but as they were moving in different directions they might be compared to an immense electrical machine, of which the upper cloud was the conductor, the lower the disc, and the wind the motive force. The moisture of the air served as a conductor for a continuous silent discharge of the electricity that was induced by the motion of the clouds. In order to test his theory, he connected an electrical machine with an insulated disc. Upon electrifying the disc with electricity of the same kind as that of the machine and moistening the air between the disc and the ground, while the machine turned rapidly in a warm and dry air, he produced columnar flashes similar to those of the storm.—*Les Mondes.* C.

Franklin Institute.

HALL OF THE INSTITUTE, Jan. 18, 1882.

The stated meeting was called to order at 8 o'clock P.M.

There were present 124 members and 20 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers and announced that at the last meeting of the Board 25 persons were elected members of the Institute.

The Actuary read the following Report of the Board, which on motion was adopted:

ANNUAL REPORT OF THE BOARD OF MANAGERS.

The Board of Managers of the Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, respectfully reports for the past year of 1881.

Members.—During the year 200 members have been elected, and 26 have resigned.

Treasurer's Report.—The following is a condensed summary of the Treasurer's report for the year ending December 31, 1881:

Receipts.		
Balance on hand Jan. 1, 1881,	$1,510 01	
Investments paid to Institute,	1,000 00	
Receipts from all other sources,	12,839 96	
		$15,349 97
Payments.		
Amount re-invested,	$820 00	
All other current payments,	13,240 33	
Balance, Dec. 31, 1881,	1,325 64	
		$15,349 97
Showing decrease in money invested,		$180 00
decrease in cash,		184 37
		$364 37

The increased value of the property of the Institute, held for the promotion of its legitimate objects, far exceeds this sum.

Library.—The Board estimates the annual increase of the money value of the Library for the last five years at two thousand dollars, or ten thousand dollars in all, and the design is to continue the improvement at the same rate.

The Board of Managers call especial attention to the complete records of scientific discovery and inventions contained in the Library. In this respect we possess a collection which is probably unequalled in value by any other similar collection in this country. The practical recognition of this fact is shown by the frequent use which is made of the Library by persons visiting it from all parts of the country.

Your Committee on the Library will present the annual report of matters under its charge. The want of room for the proper arrangement of books is increasingly felt.

Journal.—There is no change to note in the management of the JOURNAL, except that we now print a larger edition of the increased size noticed in the last annual report.

Lectures.—In the beginning of the year Prof. Edward D. Cope delivered a course of four illustrated lectures on Geology, followed by two lectures from Prof. Persifor Frazer on "Modern Methods in Geological Research"; two from Mr. Hector Orr on the "Rise and Progress of Manufactures in Philadelphia;" four from Prof. Henry Hartshorne on Hygiene; a lecture from Mr. Alexander E. Outerbridge, Jr., on the "Fourth State of Matter," illustrated with Prof. Crookes' apparatus; two from Mr. D. S. Holman on the "Microscope and its Revelations"; two from Prof. Pliny E. Chase on Astronomy; two from Mr. Robert Briggs on "Machine Design and Construction"; two from Mr. W. B. Cooper on "Drainage and Disease and Utilization of Sewage"; a lecture from Mr. John Carbutt on "Modern Photography and Gelatine Prints"; a lecture from Dr. Samuel Chamberlaine on "Silk and its Culture", and one from Mr. Robert Grimshaw on Electrotyping.

In November the course was opened by four lectures from Mr. C. Henry Roney on Civil and Mining Engineering; a lecture by Mr. Coleman Sellers, Jr., on Mechanical Drawing; one from Theodore D. Rand, Esq., on the Microscope and Polarized Light in Mineralogy, and one from Mr. John H. Ryder, of the United States Fish Commission, on the Growth and Structure of the Oyster. A course of six illustrated lectures upon Mechanics by Prof. S. T. Skidmore, and eight experimental ones on Modern Chemistry by Mr. Henry Trimble were also commenced early in December, and are now being delivered to highly appreciative audiences. Mr. D. S. Holman also gave, during the Christmas holidays, a lecture to young people on the "Wonders of the Microscope," the Hall not being able to contain all that wished to attend.

The Board of Managers, at their meeting in October, appointed, upon the recommendation of the Committee on Instruction, Coleman Sellers to be Professor of Mechanics; Edwin J. Houston to be Professor of Physics, and Persifor Frazer to be Professor of Chemistry. As an advisory board they have rendered already very valuable services to the Committee on Instruction in the selection and arrangement of the courses in their respective departments this winter. The joint committee decided, with the approval of the Board, to give to members the additional privilege of bringing a friend with them at any time to the lectures. Complimentary tickets, admitting at 5 minutes to 8 o'clock, have also been prepared to be distributed by members and the officers at the Institute, so that, practically, the lectures are now, as last year, free to the public. The average attendance, however, has not been so great this year, but the members inviting the audience is thought to be an improvement upon the former plan, and those who have attended the lectures have expressed themselves as much pleased with it. Important courses are still to be delivered on Astronomy, Chemistry Applied to the Arts, and Physics. Members will do well to attend these lectures, among the many privileges they have in connection with the Institute.

Drawing School.—No work connected with the Institute has shown greater progress than this, while the number of pupils enjoying the advantages offered by the thorough instruction in this department has been nearly double that of last year, taxing the resources of the Institute and its school rooms to the utmost.

Early in the autumn the resignation of Mr. Philip Pistor from the direction of the school, owing to other engagements, necessitated the choice of a successor, and the committee were fortunate in securing Mr. William H. Thorne to fill the position which had been so ably done by Mr. Pistor. The same general plan of instruction has been followed, with some few changes that experience had shown would be desirable, and the course of instruction extending over two years is a progressive one, as formerly, the classes, however, being frequently re-arranged according to the relative ability and success the pupils display.

Particular attention has been given to the technicalities of drawing, such as the proper selection, the use and care of instruments and materials, the making of clear and perfect lines in pencil and ink, the use of the brush and colors, the relative arrangement of the different

views of an object, and other conventionalities of practical draughting. Instruction has also been given in the modern practice of projections, the plotting of mechanical movements and gearing, free-hand sketching from models and patterns, and, in short, as thorough instruction in mechanical drawing, based upon practical methods, as the time will allow. Special classes in architectural and machine drawing have also been started, but the regular course is the one recommended to the student.

Certificates of merit will also be given at the end of the course and the Bartol scholarships of free instruction in the second term awarded to twelve of the most deserving pupils during the first term.

This drawing school has now been carried on for more than half a century, and the Board of Managers are not only unanimously agreed upon its great importance, but that it represents to an eminent degree the useful work of the Institute.

Sections.—During the last year Mechanical and Chemical Sections were established, composed of members interested in these branches, at which original papers are presented and discussed. The Phonetic Section is also kept up, and the Actuary of the Institute has had large classes attending his instruction in this department of useful knowledge.

In the last annual report of the Board the crowded condition of every branch of the Institute was clearly presented, and it was stated that "the drawing school alone has room to grow." The drawing school is now occupied to its full capacity, and there is no exception to be made. The necessity for new and enlarged accommodation is more and more apparent.

Under the pressure of this necessity the Board of Managers during the last year authorized to be set on foot a subscription to a building fund of $200,000, and a full committee of the Institute was appointed to obtain subscriptions. The amount subscribed up to the first of the year amounted to over $50,000, contingent upon the whole amount being raised. It will require a steady and persistent effort on the part of the committee, and a generous liberality on the part of the public, to complete this subscription. Meanwhile it is urged upon every member to make known the character and benefits of the Institute, that the membership may be increased.

By order of the Board,

W. P. TATHAM, *President.*

The Chairman of the Library Committee presented the following report, which on motion was adopted:

The Library.

The Committee on the Library respectfully report that the number of volumes added to the Library during the past year was—

Volumes.	Bound.	Unbound.	Pamphlets.	Maps.
By purchase, . . .	100	16	93	
Donations received, . .	243	201	262	4
Exchanges, . . .	162			
Books other than exchanges, .	84			
Additions in 1881, . .	589	217	355	4

The total number of bound volumes in the Library December 31, 1881, was 15,968.

Exchanges.—13 foreign and 7 domestic exchanges for the Journal of the Institute have been added to the list during the past year. The monthly number of exchanges for the Journal is:

Foreign, . . .	103	
Domestic, . .	77	
City, . . .	19	
	——Total, .	199

Duplicates.—A list of duplicates has been printed to aid in effecting exchanges. Books to the value of about $69 have been exchanged, and the committee hope that by the aid of the printed list, they will be able to continue the exchange of duplicates for other volumes valuable to the Library.

Serial Publications.—Six valuable serials have been completed during the year. The valuable work of Chief-Engineer Isherwood, "Experimental Researches on the Steam Engine," has been completed by the donation of the first volume by Mr. B. H. Bartol.

The purchase of the photographs of the Suez Canal, with the reports of M. Lesseps and others on its construction, is a valuable addition to our literature on this important work.

The Charts of the United States Coast Survey, secured some two years ago, have been mounted, numbered according to the catalogue, and placed in a suitable case convenient for reference. These charts are now much used by those interested in this department.

The Charts of the Light House Board of the United States, of

which the Library possesses a full set, will, when mounted in the same way, afford a ready reference to them.

The Librarian has prepared a chronological table of American patents published in the Journal of the Institute between the years 1826 and 1859 inclusive. By means of this table, the volume containing the claims of an invention can at once be found, and will be a valuable addition to a set of the Journal. The table is published in the January number of the Journal, 1882.

An alphabetical Index of names of persons to whom patents have been granted in foreign countries is now in progress by the Librarian. When finished, this index will add greatly to the convenience of those having occasion to consult foreign patent records.

We believe that the Library of the Institute is the only Library in the United States wherein can be found the British, Australian, Canadian, French, and United States patent records which are open to the free inspection of the public.

List of Additions to the Library.—By direction of the Committee on Library, an alphabetical list of books added to the Library was printed in the October number of the Journal, 1881, and the second list in the number of January, 1882. It is the intention that this list will be continued quarterly.

Bloomfield Moore Fund.—The annual interest received from the generous donation of $10,000 from the estate of our late highly esteemed fellow-member B. H. Moore, has been expended in the purchase of suitable volumes, which will be appropriately marked, as purchased by the proceeds from this fund. The additions made to the Library from this fund will be a *growing* remembrance of the interest taken by Mr. Moore in the Franklin Institute.

The Library of the Institute now contains one of the most complete collections of works appertaining to science and the arts to be found in America. Its value as a library of reference is attested by the number of persons, both at home and from distant sections, who make use of it for this purpose.

Our present building will soon cease to afford proper accommodations for the Library, and in the event of a disaster from fire in the thickly built up neighborhood, it will imperil a collection which it will be difficult to restore by the money value represented.

CHARLES BULLOCK, *Chairman of Committee on the Library.*

Philadelphia, January, 1882.

The Trustee of the Institute in the Pennsylvania Museum and School of Industrial Art presented the following report, which on motion was adopted:

REPORT OF TRUSTEE OF PENNSYLVANIA MUSEUM, ETC.

Your Trustee has great pleasure in making the following report: That very encouraging progress has been made by the pupils of the Art School under the able instruction of the Principal, Mr. Miller. At an exhibition held last spring, their work was very much admired, and showed the careful way in which they had been taught. The rooms at 1709 Chestnut street are in a very desirable part of the city, and seem admirably adapted for the purpose for which they are used.

With a view of extending the usefulness of the School, the Trustees, at a meeting held last July, decided to establish five free scholarships, to be annually filled by as many deserving pupils from the public schools, and the offer being accepted by the Board of Education, the appointments were at once made, and the pupils have been pursuing their studies ever since. The importance of introducing drawing and the manual arts, as they have been termed, into the schools, is acknowledged by nearly every one, and a very able argument upon this subject and the cultivation of art taste in a great manufacturing community like Philadelphia was delivered last summer by Mr. John S. Clark in this Hall, upon the invitation of the Board of Trade and the Franklin Institute.

If a child is taught nothing else in the schools, he should at least know how to read, to write and to draw correctly, for nothing will be of more importance to him in after life, and if the Museum School by thorough training can fit but a few persons for teaching each year, its usefulness will be acknowledged, and by the increase in its classes it can soon be made self-supporting.

The Museum is now open free to the public every day but Monday, and has attracted many thousands of delighted visitors the past year; indeed, Philadelphians are only beginning to find out what strangers have long known through their guide-books and the reports of friends that we have, owing to the wise liberality of the city and its Park Commissioners, one of the best appointed and most admirably arranged museums to be found in this country, that they may visit at any time, and take as many of their friends to see it as they please, without any charge whatever. The Secretary of the Museum, Mr. Dalton Dorr, has

been untiring in his devotion to this great work, and much credit is due to him.

The additions to the Museum have been quite extensive the past year, consisting of pottery and porcelain in great variety, enamels, glassware ancient and modern, metal work, gold and silver ornaments, ivory and wood carving, all presented by Mrs. Moore, to form the Bloomfield Moore Memorial collection, besides a number of tiles, Roman coins, medals, etc., given by other friends of the Museum.

Your representative has great pleasure in chronicling these gifts, and the bright future that seems about to dawn upon the Museum, convinced that a wise liberality in aiding such institutions cannot help but redound in the highest degree to the welfare and happiness of our people.

ISAAC NORRIS, M.D.

The Chemical Section of the Franklin Institute reported a list of their officers for 1882 and an abstract of their proceedings, and on motion, the report was accepted.

Mr. Grimshaw made a verbal report of progress from the Section of Mechanical Engineering, stating that he would have prepared a written account of its operations if he had known that it was customary or necessary to do so at the annual meeting.

The Committee on a proposed reorganization of the Committee on Science and the Arts reported progress.

The Tellers presented their report of the election, held between the hours of four and eight o'clock, 307 votes having been cast, and the President announced the result of the election, as follows:

President, William P. Tatham.

Vice Presidents, for the full term, J. E. Mitchell; for the unexpired term of Mr. Cartwright (deceased), Frederick Graff.

Secretary, Dr. William H. Wahl.

Treasurer, Frederick Fraley.

Managers—William Sellers, J. Vaughan Merrick, Hector Orr, Cyrus Chambers, Jr., Prof. William D. Marks, William V. McKean, Henry R. Heyl, and Prof. Robert E. Rogers.

Auditor, William B. Cooper.

Trustee in Pennsylvania Museum and School of Industrial Art, Dr. Isaac Norris.

On motion of Mr. Burk, a vote of thanks was tendered to the tellers for their services.

Mr. John Carbutt described the process of taking dry plate photographs, the cheapness of the apparatus, ease of manipulation, etc., and illustrated his remarks by displaying in the lantern many beautiful slides made by amateurs, particularly landscapes and views of animals in the Zoological Garden, taken instantaneously.

Mr. Robert Grimshaw described briefly the process of manufacturing beet root sugar, and said that, if American farmers would accept the experience gained in Europe during the last hundred years in the cultivation of beets for sugar making, they would get as good results as are obtained in Europe and make more money. The only way to compel them to pay attention to the character of the beets they grow is to pay them for the product in proportion to the percentage of crystallizable sugar contained in their beets, and this is being done in Delaware.

In answer to inquiries, Mr. Grimshaw said that the reason American farmers did not get as much from their beet farms as they theoretically should get, was that they did not pay strict attention to the ascertained conditions of perfect success. They seemed to suspect that the manufacturer had some sinister motive when he recommended any particular kind of beet or mode of culture, and by sacrificing the root for top plant, and by failing to gather the crop at the proper time when it contained its highest percentage of crystallizable sugar, they defeated their own purpose and lost money, or failed to make as much as they might have made. Time, however, will correct this evil.

The Secretary's report included a description of the Diamond Steam Engine, which was exhibited by Thomas J. Fales. It is similar to the Baxter engine, but contains some improvements, whereby it is claimed to be made more economical and easier to clean. The cylinder is enclosed in a superheating chamber, into which the exhaust steam passes without coming in contact with the air. It passes thence to a vacuum chamber which holds the coils that feed the boiler, and thence to the hot-air flue, exhausting into the stack, and thereby aiding the draught. The coil for feed water is made of larger pipe than the feed or outlet, thus allowing the water to lie in it longer or until it is heated almost to the boiling point. There are various improvements in mechanical details, whereby it is claimed that the boiler may be more readily cleaned than in the Baxter engine, and the cylinder itself, and, indeed, all parts of the engine, be taken apart and removed without interfering with the boiler if the latter is being used for heating purposes.

Perret's Patent Floor Furnace, drawings of which were exhibited by Ostheimer Bros., is designed to burn the cheapest kinds of fuel, such as coal dust without previous preparation, and is used for heating purposes. It is very cheaply constructed, and consists of four platforms or floors of fire-brick and an ash-pit. The front has four openings corresponding to the floors. The two upper ones serve for charging the fuel upon the floors, and the two lower ones for cleaning out the ashes and working the furnace. Heated air from the flues located at the ends of the furnace is supplied to the furnace to the height of the third floor, burning the fuel over which it passes. Combustion is effected by the heated air, and the use of the firebrick floors is to hold the dust used as fuel. As the floors are set close together, the heat from them aids the combustion. The furnace is charged only twice a day, does not require skilled labor, and the heat given forth is said to be uniform in temperature. These furnaces have been used in a number of offices, etc., in France, and one is employed in this city to heat the warehouse of Ostheimer Bros.

Perret's Grate is another invention designed for the burning of fine dust or "breeze" from anthracite coke or soft coal. It is composed of a series of upright bars, set very closely together, with their lower parts immersed in water. The air for combustion passes between the water and upper surface of the bars on which the fuel rests, and finally traverses the grate itself.

Walden's Tension Belt Tightener was described, and a model shown. It is designed to tighten both sides of a belt alike, and to put on any desired degree of tension, the latter being measured by a dynamometer or spring balance. The fastening by hooks or lacing is done while the tension is on. The Sayre Wire Centre Belting was also shown. It has wire gauze between the plies, and is claimed to be much stronger than other two-ply leather belting.

Mr. Henry Troemner exhibited one of his beautiful Analytical Balances, the knife edge of which is made of iridium. Queen & Co., a magnificent cut crystal of Iceland spar, also one of platino cyanide of magnesium, and a tube containing liquefied carbonic acid gas, which, upon being warmed in the hand, expandedto completely fill the tube.

On motion, the Institute adjourned.

ISAAC NORRIS, M.D., *Secretary.*

JOURNAL

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A NEW THEORY OF THE SUSPENSION SYSTEM WITH STIFFENING TRUSS.

By A. JAY DUBOIS, PH.D.

Professor of Dynamic Engineering in the Sheffield Scientific School of Yale College.

(Continued from page 133.)

BEST RATIO OF HEIGHT OF TRUSS TO VERSINE OF CABLE.

The deflection of the cable at the centre is, then, from (16),

$$\Delta_1 = \frac{3}{4}\lambda_1 \frac{l^2}{v} \tag{21}$$

where $\lambda_1 = \dfrac{H}{E_1 F_0}$ and F_0 is the cross-section due to strain at ends.

The deflection at the centre of a beam, fixed horizontally at both ends, when the beam is uniformly loaded with the load m per unit of length, is

$$\Delta_2 = \frac{m l^4}{24 E_2 I_2}$$

For a braced girder we may take the radius of gyration equal to $\dfrac{h}{2}$, when h is the depth of girder. Hence $I_2 = \dfrac{F_2 h^2}{4}$ where F_2 is the total cross-section of both the flanges at the centre. We have, then,

$$\Delta_2 = \frac{m\, l^4}{6\, E_2 F_2 h^2}$$

If we take moments about the centre of the span, we have for the strain in either flange, since the moment at the centre is $\frac{m\, l^2}{6}$,

$$\text{Strain} = \frac{m\, l^2}{6\, h}$$

From (III), then,

$$\lambda_2 = \frac{S}{\frac{F}{2} E_2} = \frac{m\, l^2}{3 E_2 F_2 h}$$

We have then

$$\Delta_2 = \frac{1}{2}\, \lambda_2\, \frac{l^2}{h} \qquad (22)$$

Equating (22) and (21), we obtain for the best ratio of height of truss to versine of cable,

$$\frac{h}{v} = \frac{2}{3}\, \frac{\lambda_2}{\lambda_1} \qquad (V)$$

Since the cable is always in tension we can take a higher unit strain for it than for the truss, even when they are of the same material. If of wire, the unit strain may be considerably greater than the unit strain in the truss. Moreover, the tops of the towers may give somewhat, and this has the same effect as an increase of λ_1.

Example.—Let the material in cable and truss be wrought iron. Take the coefficient of elasticity at say 24,000,000 pounds per square inch, or 12,000 tons. If, then, we assume the safe unit strain for the truss 4 tons, and for the cable, if of wire, 7 tons per inch, we have

$$\lambda_1 = \frac{S}{F_1 E_1} = \frac{7}{12000} \text{ and } \lambda_2 = \frac{S}{F_2 E_2} = \frac{4}{12000}$$

We have, then, from (V),

$$\frac{h}{v} = \frac{2}{3} \times \frac{4}{7} = \frac{8}{21} = 0{\cdot}4 \text{ nearly.}$$

In a similar manner we can find $\frac{h}{v}$ in any special case.

Load Due to Change of Temperature.

A fall of temperature causes the cable to shorten. The effect of this is the same as a uniform upward load over the truss and an equal

downward load over the cable. Let this load be equivalent to q per unit of length. We may call q the unit "cold load." This load pulls the truss up and acts as a downward load, therefore, on the cable. The actual rise at the centre of cable is, then, the rise due to change of length, minus the deflection due to cold load.

The rise due to change of length is, from (16), $\frac{3}{4}\ \varepsilon\ t\ \frac{l^2}{v_1}$. The horizontal tension at centre of cable, due to load q, per unit of length is, approximately, since in this case v and v_1 are nearly equal, $H = \frac{q\ l^2}{2\ v_1}$. The elongation at centre due to this tension is, for constant cross-section, F_0, from (III)

$$\lambda_1 = \frac{H}{E_1 F_0} = \frac{q\ l^2}{2\ v_1 E_1 F_0}$$

where F_0 is the cross-section due to the strain *at ends*.

The deflection corresponding to this elongation is from (16)

$$\frac{3}{4}\ \frac{q\ l^2}{2\ v_1 E_1 F_0}\ \frac{l^2}{v_1} = \frac{3\ q\ l^4}{8\ v_1^2\ E_1\ F_0}$$

The actual rise of the cable is, then, at centre

$$\varDelta_1 = \frac{3}{4}\ \varepsilon\ t\ \frac{l^2}{v_1} - \frac{3\ q\ l^4}{8\ v_1^2\ E_1\ F_1}$$

The upward deflection of the truss at the centre is

$$\varDelta_2 = \frac{q\ l^4}{24\ E_2\ I_2}$$

or putting $I_2 = \frac{F_2\ h^2}{4}$,

$$\varDelta_2 = \frac{q\ l^4}{6\ E_2\ F_2\ h^2}$$

Equating these two deflections, we obtain

$$q = \frac{2\ \varepsilon\ t\ E_1\ F_0\ v_1}{l^2\left(1 + \frac{4\ E_1\ F_0\ v_1^2}{9\ E_2\ F_2\ h^2}\right)} \qquad \text{(VI)}$$

From this equation we can find the temperature load q, or that unit load which would give the same strains as are caused by change of temperature.

For a fall of temperature, this load, or the "cold load," is carried

by the cable, and bends the girder upwards. For a rise of temperature, the "hot load" is carried by the truss alone.

The strains in each case must be combined with those caused by the dead and live loads, in such a way as to give the greatest strains which can ever occur.

Example.—If we take as before, $\varepsilon\, t = \frac{1}{2000}$ and assume $E_1 = E_2$, $\frac{h}{r} = \frac{1}{3}$ and $\frac{F_0}{F_2} = \frac{1}{2}$, we have, taking $E_1 = E_2 = 12{,}000$ tons per sq. inch, $l = 400$ feet, $r = 50$ feet and $F_0 = 200$ sq. inches, from (VI)

$$q = 0{\cdot}25 \text{ ton per foot.}$$

as the load on cable for fall of temperature, or the load on truss for rise of temperature.

Live Load over Entire Span.

Let the live load m per unit of length cover the entire span. A portion of this load acts as a uniform load upon the cable, and a portion as a uniform load upon the truss. Let $n\, m$ be the portion carried by the cable. Then $(1 - n)m$ is the load of the truss. We have from (18a) for the deflection of cable at centre,

$$\Delta_1 = \frac{3nml^4}{8E_1F_0r_1r}.$$

The deflection of the truss is

$$\Delta_2 = \frac{(1 - n)ml^4}{24E_2I_2},$$

or putting $I_2 = F_2\frac{h^2}{4}$ where h is the depth of truss,

$$\Delta_2 = \frac{(1 - n)ml^4}{6E_2F_2h^2}.$$

Equating these two deflections, we obtain

$$n = \frac{1}{1 + \frac{9}{4}\frac{E_2F_2h^2}{E_1F_0r_1r}} \tag{VII}$$

Partial Uniform Load.

Under the action of a partial load which extends only over a portion of the span, the curve of the cable is no longer a parabola, and the

greatest deflection is no longer at the centre. As the office of the truss is to prevent deformation, it acts to distribute the partial load over the cable. But as the curve of the cable is no longer parabolic, the distributed load cannot be regarded as uniform, and, in fact, is not uniform.

If we suppose, however, that the cable load is uniform, we can easily find that portion of the partial load which would act, in such case, upon the cable as a uniform load. Although the supposition is not correct, we shall have future use for this result, and we therefore deduce it here.

Suppose a partial load m per unit of length, to extend over a distance *a from each end.* These two loads being equal and symmetrically placed, will cause a uniform load over the cable, the curve of which is therefore still a parabola. Of the whole load $2ma$, let the amount $2km$ act as a uniform load per unit of length on the cable, km being the unit load due to *each partial load.*

Then the deflection of the cable at the centre is from (19a)

$$\varDelta_1 = \frac{6kml^4}{8E_1F_0r_1r}.$$

The deflection of the truss at centre is equal to the deflection which would be caused by the two weights acting alone, minus the upward deflection due to the reaction of cable, or the upward load on the truss.

The first deflection, putting $I_2 = F_2\frac{h^2}{4}$, is

$$\frac{m}{6E_2F_2h^2}\left[2la^3 - a^4\right].$$

The second deflection is

$$\frac{2kml^4}{6E_2F_2h^2}.$$

The actual deflection of the truss at the centre, is then

$$\varDelta_2 = \frac{m}{6E_2F_2h^2}\left[2la^3 - a^4\right] - \frac{2kml^4}{6E_2F_2h^2}.$$

Equating $\varDelta_1$ and $\varDelta_2$, we obtain

$$k = \frac{2la^3 - a^4}{2l^4\left[1 + \frac{9E_2F_2h^2}{4E_1F_0r_1r}\right]} \qquad \text{(VIII)}$$

This equation gives the value of k for any value of a from 0 to l. If the load extends from the left end *beyond* the centre, we have

$$k = \frac{2l^4 - a(2l - a)^3}{2l^4\left[1 + \frac{9}{4}\frac{E_2F_2h^2}{E_1F_0r_1v}\right]} \qquad \text{(VIII}a\text{)}$$

In either of these equations, when $a = l$, the value of k becomes equal to half of n as given by (VII) as should be. For varying cross-section of cable, put F_1 for F_0.

Approximate Values of F_0, F_1 and F_2.

The use of the equations thus far deduced requires that F_0 and F_2, the cross-sections at end of cable and centre of truss, should be known. But these are the very quantities which are to be found. It is therefore necessary to make a preliminary, if not very exact, estimate of these cross-sections, before we can use our formulæ. The strains being then found, we can determine the corresponding cross-sections. If they do not agree well enough with their assumed values, a second approximation can be made.

We see from (VI), (VII) and (VIII), that very considerable variations in the ratio $\frac{F_2}{F_0}$, will have but slight effect upon the resulting values of q, n and k. Our approximation need not then be very exact.

We may suppose the cable to carry the load $p + m$ per unit of length. This is an error in excess, because really the cable carries only a portion of the live load m. The "cold load" q, however, which, for the present, we neglect, tends to balance this error. We may also take $v = v_1$.

The horizontal tension at centre of cable would then be approximately

$$H = \frac{(p+m)l^2}{2v}.$$

The secant of the angle of inclination at the ends would be from (11)

$$\frac{ds}{dx} = 1 + \frac{2v^2}{l^2}.$$

Hence, the strain at the ends is

$$S_0 = \frac{(p+m)l^2}{2v}\left(1 + \frac{2v^2}{l^2}\right).$$

Let the greatest allowable unit strains for the cable be f_1, then

$$\text{approx. } F_0 = \frac{S_0}{f_1} = \frac{(p+m)l^2}{2vf_1}\left(1 + \frac{2v^2}{l^2}\right) \tag{IX}$$

From equation (IX) we can compute approximately the cross-section F_0 at the ends of cable, or the constant cross-section of cable.

The cross-section F_1 at the centre of the cable, if the cross-section varies with the strain is also approximately

$$\text{approx. } F_1 = \frac{H}{f_1} = \frac{(p+m)l^2}{2vf_1} \tag{IXa}$$

We may also find a preliminary value of n, by putting $\frac{F_2}{F_0} = 1$ and $v_1 = v$ in equation (VII). We have then approximately

$$\text{approx. } n = \frac{1}{1 + \frac{9E_2h^2}{4E_1v^2}} \tag{23}$$

We can now find the preliminary value of q by putting $\frac{F_0}{F_2} = 1$ in (VI). Thus

$$\text{approx. } q = \frac{2\varepsilon t E_1 F_0 v}{l^2\left(1 + \frac{4E_1v_2}{9E_2h^2}\right)} \tag{24}$$

For varying cross-section put F_1 in place of F_0.

We can now compute an approximate value for F_2.

Thus we may consider the truss loaded with $(1 - n)\,m + q$ per unit of length, where q is the "hot load." The moment at centre of truss is then

$$\frac{[(1-n)\,m + q]l^2}{6}$$

The strain in each flange at the centre is then

$$\frac{[(1-n)m + q]l^2}{6h}$$

The total area of both flanges at the centre is then, if f_2 is the greatest allowable unit strain for truss,

$$\text{approx. } F_2 = \frac{[(1-n)m + q]l^2)}{3hf_2} \tag{X}$$

Equations (IX) (IXa), (23) (24 and (X) give us approximations to the values of F_0, F_1 and F_2 sufficiently exact for our purpose.

Greatest Deflection and Strain in the Cable.

We can now find the strain at any point of the cable.

The greatest strain in the cable will occur when the dead load, live load and temperature load, all act. The uniform load of the cable then will be $p+nm+q$. The dead load p per unit of length and the live load m per unit of length are supposed to be known. We can find n and q from (VII) and (VI) with the aid of (X) and (IX).

The deflection at the centre then of cable is from (IV).

$$\Delta_1=\frac{3(p+nm+q)l^4}{8E_1F_0v_1v} \tag{XI}$$

For varying cross-sections we must put F_1 in place of F_0 in all formulæ. The new versine v_1 is given by (14.) It will in general be so nearly equal to v that small error will be committed by taking them equal.

The greatest horizontal tension at centre of cable is then

$$H=\frac{(p+nm+q)l^2}{2v_1} \tag{XII}$$

The strain at any point is H sec. i, where i is in the angle of inclination of cable at that point to horizontal. From (11) we have

$$\text{sec. } i=\frac{ds}{dx}=1+\frac{2v_1^2x^2}{l^4}$$

Hence the strain at any point is

$$S=\frac{(p+nm+q)l^2}{2v_1}\left(1+\frac{2v_1^2x^2}{l^4}\right) \tag{XIII}$$

where x is the distance of point from centre. If the cross-section is constant, it must be determined from the greatest strain, or making $x=l$ in (XIII). We have then the constant cross-section.

$$F_0=\frac{S_{x=l}}{f_1}=\frac{(p+nm+q)l^2}{2v_1f_1}\left(1+\frac{2v_1^2}{l^2}\right) \tag{XIV}$$

If the cross-section varies, the cross-section at the centre is

$$F_1=\frac{H}{f_1}=\frac{(p+nm+q)l^2}{v_1f_1} \tag{XV}$$

These cross-sections thus found ought to agree satisfactorily with our approximate values found from (X) and (IX). If they do not, another and better approximation can be made.

We can thus easily find the deflection at the centre and the strain at

any point, whether the cross-section is constant or varies according to the strain.

A discussion of the side spans, if any, is unnecessary so far as the cable is concerned. If the cable is of uniform cross-section it must evidently remain of the same cross-section for the side spans also. If it varies in cross-section, it will be sufficient to make the area of the cable at any point in the side span equal to its area at the corresponding point of the centre span, whatever the length of the side span.

Estimate of the Dead Weight.

In any given case, n and q are given by (VII) and (VI). We also know m or the unit live load. But p, or the unit dead load, depends upon the weight of the truss and cable, or upon F_0 or F_1 and F_2, and these are the very quantities it is required to determine. We must therefore make a preliminary estimate of the unit dead load p. The dead load consists of the weight of the floor system and wind bracing, etc., the weight of the cable and the weight of the truss. Of these, the weight of floor system, wind bracing, etc., can be very exactly estimated for any special case and system. The weight of cable can be easily estimated from (IX) and (IXa). Thus if the cross-section of cable is uniform, the cubic contents of cable are

$$F_0 s_1 = 2F_0 l\left(1+\frac{2v_1^2}{3l^2}\right) \tag{25}$$

where v_1 is given by (14).

This multiplied by the weight of a cubic unit of cable which is known of course, will give the weight of cable. We may take this weight as uniformly distributed and add it to weight of floor system, etc.

If cross-section of cable varies, it will be near enough to take the mean area, or $\frac{F_1+F_0}{2}$, and multiply by the length or

$$\frac{F_1+F_0}{2}s_1 = (F_1+F_0)l\left(1+\frac{2v_1^2}{3l^2}\right) \tag{26}$$

Lastly, for the weight of truss, we have for the cubic contents of the flanges $2F_2 l$, assuming that the flanges are constant. This multiplied by the weight of a cubic unit of the material of the truss will give an estimate of weight of girder. As the flanges are not uniform in cross-section, the estimate is too large. But the error in this direction is balanced by the weight of bracing, which we neglect.

We can thus estimate p closely enough for our purposes. The strains in the cable can then be found.

Recapitulation of Formulæ Necessary for Calculation of Cable.

For convenience of reference, let us now group together the formulæ thus far deduced, in the order required for calculation.

We have for the best ratio of height of truss to versine of cable

$$\frac{h}{v} = \frac{2\lambda_2}{3\lambda_1} = \frac{2f_2}{3E_2\frac{f_1}{E_1}} \tag{V}$$

For preliminary estimate, we have next

$$\text{approx. } n = \frac{1}{1+\frac{9E_2h^2}{4E_1v^2}} \tag{23}$$

$$\text{approx. } F_0 = \frac{(p+m)l^2}{2vf_1}\left(1+\frac{2v^2}{l^2}\right) \tag{IX}$$

$$\text{approx. } F_1 = \frac{(p+m)l^2}{2vf_1} \tag{IXa}$$

$$\text{approx. } q = \frac{2\varepsilon tE_1F_0v}{l^2\left(1+\frac{4E_1v^2}{9E_2h^2}\right)} \tag{24}$$

$$\text{approx. } F_2 = \frac{[(1-n)m+q]\,l^2}{3hf_2} \tag{X}$$

These approximate values being thus determined, we have

$$v_1 = v\left[1+\frac{\lambda_1}{2}\left(1+\frac{3l^2}{2v^2}\right)\right] \tag{14}$$

where $\lambda_1 = \frac{f_1}{E_1}$ when the cross-section of cable varies according to the strain, and $\lambda_1 = \frac{F_1}{F_0}, \frac{f_1}{E_1}$ when the cross-section of cable is constant.

We have now the accurate value

$$n = \frac{1}{1+\frac{9E_2F_2h^2}{4E_1F_0v_1v}} \tag{VII}$$

where we put for F_2 and F_0 their approximate values as determined by

(X) and (IX). For varying cross-section of cable, we put F_1 in place of F_0. For a fall of temperature of t^0 below the mean, the uniform "cold load" of cable per unit of length is

$$q = \frac{2\varepsilon t E_1 F_0 v_1^2}{l^2 \left[1 + \dfrac{4E_1 F_0 v_1^2}{9E_2 F_2 h^2}\right]} \qquad \text{(VI)}$$

For varying cross-section of cable, put F_1 in place of F_0. For rise of temperature, q is the "hot load" of truss.

For a partial distributed load, ma, covering a distance, a, from the left end, upon the supposition that the curve of the cable remains a parabola, with the vertex at the centre, the equivalent uniform load on the cable per unit of length is, when a is less than the half-span or when $a < l$

$$k = \frac{a^3(2l - a)}{2l^4 \left[1 + \dfrac{9E_2 F_2 h^2}{4E_1 F_0 v_1 v}\right]} \qquad \text{(VIII)}$$

when $a > l$

$$k = \frac{2l^4 - a(2l - a)^3}{2l^4 \left[1 + \dfrac{9E_2 F_2 h^2}{4E_1 F_0 v_1 v}\right]} \qquad \text{(VIII}a\text{)}$$

For the deflection due to a uniform load, u, per unit of length, we have

$$\delta_1 = \frac{3ul^2}{8E_1 F_0 v_1 v}(l^2 - x^3) \qquad \text{(IV)}$$

where x is the distance of the point from the centre.

For varying cross-section of cable, always put F_1 in place of F_0.

For the maximum deflection at the centre of cable,

$$\Delta_1 = \frac{3(p + nm + q)l^4}{8E_1 F_0 v_1 v} \qquad \text{(XI)}$$

For varying cross-section put F_1 in place of F_0.

The greatest horizontal strain at centre of cable is now

$$H = \frac{(p + nm + q)l^2}{2v_1} \qquad \text{(XII)}$$

The strain at any point of cable, distant x from centre is

$$S = \frac{(p + nm + q)l^2}{2v_1}\left(1 + \frac{2v_1^2 x^2}{l^4}\right) \qquad \text{(XIII)}$$

The constant cross-section of cable is

$$F_0 = \frac{(p-nm+q)l^2}{2r_1f_1}\left(1+\frac{2r_1^2}{l^2}\right) \qquad \text{(XIV)}$$

The cross-section at centre, if cross-section varies with the strain, is

$$F_1 = \frac{(p+nm-q)l^2}{2r_1f_1} \qquad \text{(XV)}$$

Example.—Take, for instance, the Niagara bridge, the span of which $2l = 800$ feet, $r = 60$ feet. Take $E_1 = E_2 = 12{,}000$ tons per sq. inch, and let the greatest allowable strain in the cable be $f_1 = 10$ tons and in the truss $f_2 = 4$ tons per sq. inch. Take $e = 0{\cdot}00000686$ for one degree Fahr. and let $t = 70°$ above or below the mean temperature of erection. Then $\varepsilon t = \frac{1}{2000}$.

Let also $m = 1$ ton per foot and estimated $p = 0{\cdot}5$ ton per foot.

Then from (V) we have for best height of truss

$$h = \frac{2\times4\times60}{3\times12000\times\frac{10}{12000}} = 16 \text{ feet.}$$

From (23) we obtain

$$\text{approx. } n = \frac{1}{1+\dfrac{9\times256}{4\times3600}} = 0{\cdot}9 \text{ nearly.}$$

We have also from (IX) and (IXa)

$$\text{approx. } F_0 = \frac{1{\cdot}5\times160000}{2\times60\times10}\left(1+\frac{2\times3600}{160000}\right) = 209 \text{ sq. inches.}$$

$$\text{approx. } F_1 = \frac{1{\cdot}5\times160000}{2\times60\times10} = 200 \text{ sq. inches.}$$

We can now estimate from (24)

$$\text{approx. } q = \frac{2\times\frac{1}{2000}\times12000\times209\times60}{160000\left(1+\dfrac{4\times3600}{9\times256}\right)} = 0{\cdot}055 \text{ ton per foot.}$$

From (X) we have

$$\text{approx. } F_2 = \frac{(0{\cdot}05+0{\cdot}055)160000}{3\times16\times4} = 133 \text{ sq. inches.}$$

We have also from (14), since λ_1 for constant cross-section is $\frac{200\times4}{209\times12000}$ or $\lambda_1 = \frac{1}{3135}$

$$r_1 = r\left[1+\frac{1}{6270}\left(1+\frac{3\times160000}{2\times3600}\right)\right] = 1{\cdot}01r.$$

We may, therefore, take $v_1 = v$ without appreciable error.

We have next from (VII)

$$n = \frac{1}{1+\frac{9\times 133\times 256}{4\times 209\times 3600}} = 0{\cdot}9 \text{ ton per foot,}$$

or about the same as our first estimated value.

From (VI) we have then

$$q = \frac{2\times\frac{1}{2000}\times 12000\times 209\times 60}{160000\left(1+\frac{4\times 209\times 3600}{9\times 133\times 256}\right)} = 0{\cdot}04.$$

We have then for constant cross-section of cable, from (XIV),

$$F_0 = \frac{(0{\cdot}5+0{\cdot}9+0{\cdot}04)160000}{2\times 60\times 10}\left(1+\frac{2\times 3600}{160000}\right) = 209 \text{ sq. inches.}$$

or the same as our estimated value. For the given unit strain, this would require 4 cables of 8 inches each in diameter.

From (X), finally, we have for the deflection of cable at the centre,

$$J_1 = \frac{3\times 1{\cdot}5\times 160000}{8\times 12000\times 209\times 3600} = 1{\cdot}5 \text{ feet.}$$

(To be continued.)

New Determination of the Electric Ratio.—Prof. Stoletow, of the University of Moscow, has made some recent experiments in order to determine Maxwell's ratio between the electromagnetic and electrostatic units. The electrostatic capacity, c, of a condenser formed of two plates with plain and parallel faces is equal to $\frac{S}{4\pi\delta}$, S being the surface and δ the distance between the plates. The electromagnetic capacity is $\frac{c}{v^2}$. The condenser is charged and the discharge is received by a galvanometer; by producing 100 discharges per second the galvanometer receives a permanent deviation, from which the value of v can be determined. Stoletow's results accord very closely with those which have been previously ascertained, indicating a velocity between 298,000 and 300,000 km. (185,170 to 186,410 miles) per second.—*Soc de Physique.* C.

THE ADHESION OF FLAT DRIVING BELTS.

By Robert Grimshaw.

Abstract of Remarks made at the Meeting of the Franklin Institute, Feb. 15, 1882.

The speaker stated that he was prepared to explain certain discrepancies and add lacking points in the theories of published experiments of Morin, Briggs & Towne, Cooper and Webber. The ordinarily accepted theories were in some cases affirmed, in some modified and in some contradicted by his tests, which up to the present time numbered over 900.

The elements governing the adhesion of flat driving belts to pulleys are pulley diameter, material and condition, and amount of crown; arc of contact, and belt material and condition, width and thickness, and tension. Each of these exerts an influence upon the adhesion; these influences being modified and in some cases neutralized, or even reversed, by the others. Of only one of them (arc of contact) it may be said that there are no apparent contradictions in its action. In his experiments Mr. Grimshaw used ten changes of pulley, ten of belts, three of arc, and about ten of tension. He employed pulleys of turned cast iron, wrought iron, and wood, and also the same pulleys covered with leather and rubber lagging; these pulleys having diameters of 18, 24, 30, and 36 inches. The belts used in testing were rubber, single and double leather oak tanned, waterproof and fulled, and wire centres; and canvass covered with composition. The arcs of contact were 90°, 180°, and 270°; and the tensions from 10 to 100 pounds per inch of belt width. The machine used for testing, and which was shown in part at the meeting, consisted of a strong wooden frame bearing a shaft $2\frac{7}{16}$ inches diameter, 5 feet long, upon which were hung the pulleys to be tested—both shaft and pulleys being held from turning.

At the meeting there were turned cast iron pulleys of 18 and 36 inches diameter, and a 36-inch "taper sleeve" wooden pulley. The belt to be tested was placed centrally upon the desired pulley, and one end weighted with a given amount per inch of width. Force is applied at the other end until the belt slowly slips. The difference between the weights on each end represents the amount of friction of the belt upon

the pulley, or the grip under the circumstances. The tension is applied by dead weights in a cage (the weight of the clamps and the cage being allowed for). The force to cause slipping is preferably applied by dead weights; but as in some cases this is considerably more than a ton, for convenience in such cases the force is applied by a lever of the second class, having its fulcrum under the centre of the shaft and its point of application of force to the belt in a vertical line tangent to the pulley at the point in the horizontal plane of the shaft. In other words, for each pulley the short arm of the lever was the same length as the radius of the pulley.

The dynamometer, one of Fairbanks' standard traction machines, is first tested by hanging dead weights upon it, at each division at which it is to be used; and in testing the belts the mean of four readings is taken; although in many cases no readings are counted until there are three consecutive ones alike.

As the result of over 900 tests and readings made, Mr. Grimshaw announced that the influence of increased pulley diameter is always to increase the drive; especially with light tensions. The influence of pulley material is so largely modified by the other conditions that no general rule can be laid down concerning it. The same is true of belt material. Increasing the belt width does not always increase the driving power, especially with thick belts, small pulleys, and light tensions. Increasing the belt thickness does not always increase the driving power, especially with small pulleys, wide belts, and light tensions. Increasing the arc of contact may be said to increase the drive in every case yet known. Increasing the tension increases the drive up to a certain point, beyond which, in many cases, no further increase of tension will cause any augmentation in the grip.

Mr. Lipman inquired as to paper belts. Mr. Grimshaw answered that these were but little used, by reason of their great stiffness and lack of elasticity; a certain degree of elasticity being a prime requisite of a belt in order to permit a difference in tension between the two sides by alternate elongation and contraction.

Mr. Fagan asked which were the most durable, rubber or leather belts. Mr. Grimshaw replied that in some situations, as for instance, in dry places, leather was the most durable; while for damp places rubber only would answer. Rubber was rapidly deteriorated by mineral oils and could not be used for quarter twist and crossed belts.

Mr. Chambers asked whether the tests as made were of any value

in determining the driving power of belts at high speeds. Mr. Grimshaw replied that the conditions of friction were substantially the same, and that conditions varied so that he could not give any reply to any question as to the relative driving power of different kinds of belts at high speeds, without all the conditions being stated.

Mr. Sandgran asked if the speaker had made any tests of canvas belts. The latter replied that he had made about 200 under varying conditions with some substance to increase the adhesion, and that its tractive powers under the conditions of his tests were exceptionally good, while it was the strongest belt that he had ever broken.

Mr. Eccles thought that the mode of testing was hardly the right one, the tendency being, by adding weights to both ends of the belt, to break it; and said that he would prefer to attach the dynamometer to the rim of the pulley. Mr. Grimshaw said that the friction between the belt and the pulley was the same as that between the pulley and the belt; that the driving power of any belt was measured by the difference between the tight and the loose sides, and that the pulley got all the difference in the tension; it could go nowhere else. As regards the danger of breaking the belts—the tension possible to put upon any belt was determined by the strength of the lacing or other fastening, and that for lacings the maximum safe strain, as laid down by Briggs & Towne, was $66\frac{2}{3}$ pounds per inch wide; whereas single oak tanned leather belting broke at 1000 pounds per inch of width. Hence the method of testing not only registered correctly both the light and the heavy tension but the difference or grip, and did not induce artificial conditions. It had two certain practical conditions over attaching the dynamometer to the pulley rim.*

Preservation of Chestnuts.—The great consumption of chestnuts in France, both by men and by cattle, renders some contrivance for preserving them a great desideratum. M. Magne has communicated a method to the Agricultural Society, which he has found very successful. He mixes them, in November, with a dry sandy soil, and places them in a close vessel. When thus treated they can be preserved in good condition until the end of May or longer.—*Les Mondes.* C.

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*Attaching the dynamometer to the pulley rim allows only as much slip as the motion of the spring permits (about $\frac{1}{8}$ inch in the present case); while allowing the belt to slip gives a foot or two.—R. G.

CAR JOURNAL BOXES WITH WENDELL'S LATEST IMPROVEMENT.

By C. Henry Roney, C.E.

In cars and locomotive engines the bearing carrying the car rests upon the axle so that lubrication to be effective should be on the top of the journal, the reverse of the case in stationary engines, where the journal rests upon the bearing. In the car journal boxes in ordinary use, Fig. 1, to diminish friction, cotton waste saturated with animal or mineral oils or fat is used; acting as it does by capillary attraction, it achieves the object very imperfectly; collecting dust on the surface next to the journal, or falling away from it removes the lubricating material from contact with the journal, allowing the metal surfaces to rub together and become heated; the principal cause of hot boxes, or the grit working between the surfaces wears them away much more rapidly than where the lubrication is carried on without cotton waste.

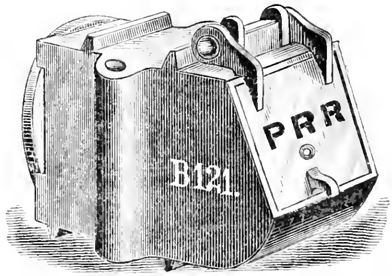


Fig. 1.—Pennsylvania R.R. Freight Box as used at present.

To overcome this deficiency Mr. Wendell has devised this improvement, consisting of a small force pump, Figs. 3, 4, 5, 6 and 8, with ball valves *C* and *D*, operated by the vertical motion of the car or truck, which pumps up oil or lubricating material from the bottom of the box through the pipe *E* to the top of the bearing, through which openings are made, carrying it directly to the top of the journal from whence it falls to the bottom of the box.

The pump (Figs. 3, 4, 6 and 8) itself is exceedingly simple in construction, consisting only of a phosphor-bronze valve seat, *H*, Figs. 4 and 6, and pump barrel, *G*, phosphor-bronze being used on account of its toughness and durability; the valves *C* and *D* are common Babbitt metal balls, while the pump plunger, *A*, is a solid piece of iron turned to fit the pump barrel, *G*, without any packing whatever, as the oil forms a sufficient packing in itself.

In the special box shown in Fig. 5 this pump, Fig. 6, is dropped into a recess in the front part of the box made to receive it, and a lid

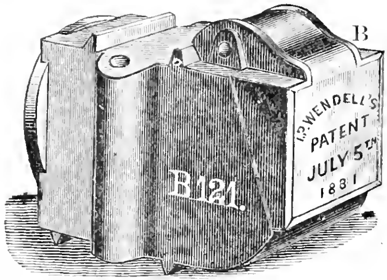


Fig. 2.—Penna. R.R. Freight Box with Wendell's Improvement.

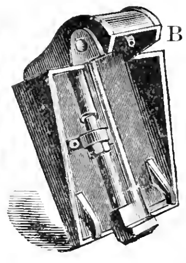


Fig. 3.—Inside View of Lid with Improvement.

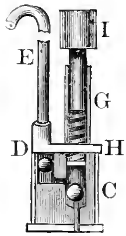


Fig. 4.—Cross-section of Pump.

or cap is put on the top and bolted down, thus holding the pump securely in place so it cannot be loosened by the continual jarring when the train is in motion. A spiral spring is placed around the upper part of the plunger, *A*, Figs. 5 and 6, so as to return it to its place after having been pressed down by the downward plunge of the car body or truck.

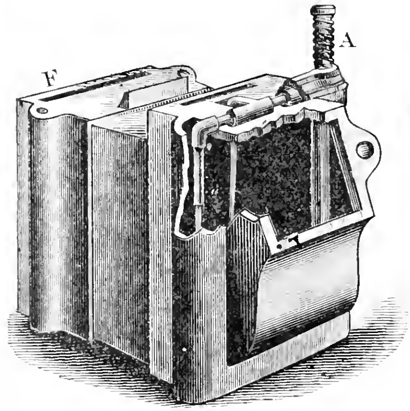


Fig. 5.—Wendell's Improvement for Steam R.R. Car Boxes.

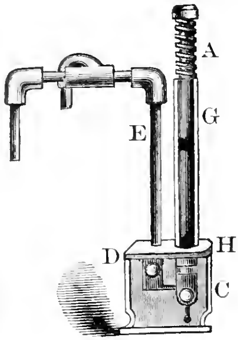


Fig. 6.—Cross-section of Pump.

Another mode of lubrication, and one that may be applied to any form of old box, Fig. 1, and consequently of much more value, is one where the pumping device, Fig. 4, is attached to the lid of the box, Figs. 2 and 3, and operated altogether by concussion, it being a weighted plunger, *I*, Fig. 4, resting on a small spiral spring of just sufficient

strength to support the plunger when the car is at rest, so that at every jar or motion of the truck the plunger will move on the spring thereby causing a small quantity of oil to be pumped up and into the bearing over the journal and thence into the bottom of the box to be again circulated. This process is constantly repeating itself while the car is in motion, consequently there is no loss of oil except such as may leak out at the shoulder of the axle or the infinitesimal portion of oil which may be oxidized or worn out.

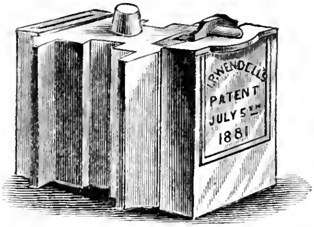


Fig. 7.—For City Passenger Cars.

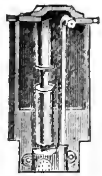


Fig. 8.—View of Pump.

By either improvement no cotton waste is used, and the oil fed to the journal is always clean and fresh, and being poured on in such quantities, any dust that may have settled on the face of either journal or bearing will be washed off and settle in the bottom of the box, where it will remain, as all the oil pumped is drawn from a sufficient distance above the bottom to allow for all settling of dirt or dust and wear.

There is a remarkably good packing around the shoulder of the journal *F*, Fig. 5, to exclude dust and dirt and prevent the waste of oil; this consists of two pieces of cork or leather cut to fit the journal, and made to break joints, so as to be contracted or expanded, by means of an iron strap and follower drawn together by small nuts, and so tighten the packing around the journal. Another plan, which renders the packing automatic, is to place one small spring under each nut, and between the nut and follower, so that the constant pressure of these springs will always keep the packing tight and prevent the escape of oil or admission of dust almost entirely, so that one supply of oil may last for a long time. This seems to be a very great improvement over the old style, where they pack the journals but loosely, and the dust getting in is sure to grind and cut the journals and bearings, and very frequently result in what every experienced traveler has cause to dislike, viz., a hot box.

With this improvement of Mr. Wendell's such a constant supply of oil is kept on the journal that a hot box is rendered next to impossible. The patentee claims that not only will this prove a great saving in the wear of bearings, as has been fully shown by many experiments of lubricating with clean oil, without waste, and from the top, but also

in power, the cars running very much lighter when the oil is fresh and clear of grit than when the cotton waste is holding all this grit and dirt up to the journal and forming a sort of emery wheel until, as is almost always the case, the bearing is worn out in one-quarter the time it would have been if the oil fed was clean.

The present cost for brasses and lubrication per eight-wheeled car per annum has been estimated (with oil at 20 cents per gallon) at $44.97. Mr. Wendell claims that by the use of his improvement a large portion of this cost may be saved.

THOMPSON'S PATENT WET PULVERIZER.

By C. Henry Roney, M.E.

Read before the Franklin Institute, January 18, 1882.

This machine in its original form has been used successfully in England for some years, but recently has been simplified and improved by S. P. M. Tasker, of Philadelphia, so that as manufactured by him it is much more effective and durable, as well as more convenient to transport and run, than the original form.

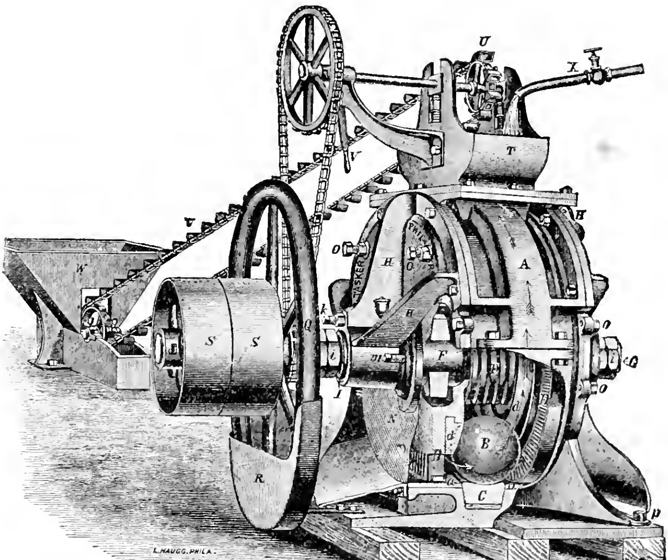
The accompanying illustration, representing a machine of a capacity of 60 tons in 24 hours, built for a Philadelphia silver mining company, will convey an accurate idea of the general character of the pulverizer, a portion of the lower portion of the machine being removed to show the working parts.

The ore fed in at *T* is crushed between the chilled charcoal iron ball *B* and the shoe ring *C* of equal hardness, the ball *B* being grasped between the disc blades *d*.

The disc blades *D D* and the disc rings *d d*, kept the proper distance apart by the spring *E*, grasping the ball *B*, are caused to revolve rapidly, and the centrifugal motion thus given the ball *B* causes it to press against the shoe ring *C* while it is being carried around by the blades, crushing any ore which may be between the ball *B* and the shoe ring *C*. At the same time that the ball is being carried around the inner circumference of the machine, it is free to revolve on an axis which is continually changing; as it is loosely grasped at two opposite points only, there is little or no scraping motion against the ring

C; and the ball always presents new surfaces against the ore, preserving its spherical form until worn down too small for further use.

The ore broken to a suitable size (about two-inch cubes) and water are fed into the hopper *T* and the pulverized ore is emitted through the screens *N* at the sides of the machine. The disc blades *D D* have diagonal slots running from the inner to the outer sides, so that any ore which is not crushed sufficiently fine at the first revolution of the ball *B* to pass through the screen *N*, is brought back under the ball and crushed sufficiently fine by succeeding revolutions.



A, Body of Machine. *a a*, Steel Wearing Plates. *B*, Ball. *C*, Shoe Ring with Wooden Cushion. *D D*, Disc Blades. *d d*, Disc Ring. *E*, Spring. *F F*, Ball Joint Clutch Journals. *G*, Shaft. *H H*, Journal Bearing Boxes. *i i i i*, Nuts for Setting Discs. *K K*, Screws for Setting Brasses. *L L*, Packing Box to Prevent Material from Getting in Journals. *m m m m*, Screws for Setting Packing Boxes. *N N*, Screens and Frames. *O O*, Screws and Clamps for Holding Screens. *P P*, Foundation Bolts. *Q*, Fly-Wheel. *R*, Fly-Wheel Fender. *S S*, Tight and Loose Driving Pulley. *T*, Hopper. *U*, Automatic Feed. *V*, Feed Clutch. *W*, Receiver for Ore. *X*, Water Supply Pipe.

Disregarding minor details, such as the driving pulleys, screens, bolts and bearings, the entire pulverizer is composed of six pieces, the bottom, the top, the disc ring and the ball. The machine is divided directly through the middle and requires no expensive foundation upon which to place it, three ordinary timbers answering all purposes and

but four bolts being required to hold it together, their removal in a few moments enabling it to be taken entirely apart.

The wearing parts of the machine, such as the ring in which the ball revolves and rolls, the discs, the ball itself are made of the best chilled charcoal iron, much harder than the best tool steel, such tools, as cold chisels, having been ground in this pulverizer to demonstrate the hardness of the metal and effectiveness of the motion.

The hardest rock may be ground with very little motive power, the largest machine—they are made of three sizes—requiring but ten horse-power to pulverize sixty to seventy-five tons of ore per day, a quantity equal to the work of a thirty-five ton stamp mill; the next smaller size will pulverize about two-thirds and the other about one-half of the amount done by the larger machine, with a proportionately small amount of power. The screen used is No. 60 mesh, and on testing the pulverized ore which passed through, it was found that 75 per cent. of it would pass through a 100 mesh screen, which is much finer than gold or silver ore is crushed by ordinary stamp mills.

In order to compare the results obtained by this pulverizer with those given for stamp mills in California, Colorado, Lake Superior Copper Mines, etc., as given by Rossiter W. Raymond, U. S. Commissioner of Mining Statistics, Prof. T. H. Eggleston, Charles M. Rolker, M.E., Aug. J. Bowie, Jr., Prof. H. S. Monroe ("Trans. Am. Inst. Mining Engineers") and E. F. Althaus, U. S. Centennial Reports, I have prepared a table, giving the maximum results obtained with stamps in different localities, together with those obtained with this machine.

In the large machine the ball, originally measuring about 11 inches in diameter and weighing 180 pounds, is used until reduced to about 9 inches in diameter and weighing 100 pounds, a loss of 80 pounds of metal, during which time about 320 tons of a hard Laurentian rock has been crushed, being about $\frac{1}{4}$ pound of iron to each ton of ore crushed; while with ordinary stamps one shoe, weighing from 300 to 320 pounds, is estimated to crush 40 tons of quartz rock before it is discarded, and loses from one to several pounds of metal to each ton of ore crushed.

The amount of water required per ton of ore for the pulverizer is also claimed to be less than one-half that required for a California stamp mill, a very important consideration, when we understand the great difficulty in obtaining water, which frequently exists in mining regions.

Location of Mill.	Stamps. Character.	Stamps. Weight—lbs.	Stamps. Fall—inches.	Stamps. Number of drops per minute.	Size of Screen.	HP per Stamp.	Tons crushed per HP in 24 hours.	Tons crushed per Stamp in 24 hours.	Shoes, wear per toncrushed—lbs.	Water required per ton crushed—gallons.	Coarseness of Sands. 1-25 in. to 3-16 in. pr ct.	Coarseness of Sands. 1-64 in. to 1-25 in. pr.ct.	Coarseness of Sands. Finer than 1-64 in. pr.ct.	Coarseness of Sands. No. 60. Per cent.	Coarseness of Sands. Finer than No. 100. pr.ct.	Space occupied—feet.	Character of Ore.
California, Eldorado County...	California Pattern..	665	10	80	No. 6	...	3·93	......	...	5282	...	...	...	...	...	....	Quartz.
California, Nevada County.....	"	1000	11	60	....	...	2·00	......	...	5282	...	...	...	...	...	....	Quartz.
Colorado, Gilpin County......	"	900	15	50	....	...	3·30	......	...	......	...	...	...	...	...	....	....
Nevada, Virginia City..........	"	......	8	100	....	...	....	$4\frac{1}{2}$	...	......	...	...	...	...	...	....	....
Dakota, Deadwood	"	758	9	85	No. 6	...	....	$3\frac{1}{10}$	...	......	...	...	...	...	...	....	Quartz.
Utah, Ontario District...........	"	800	8	92	No. 30	..	....	$2\frac{1}{4}$	...	dry	...	...	...	...	...	....	Very hard.
Michigan, Lake Superior, Calumet and Hecla.........	Ball Steam hammerst'mp	4500	20	90	$\frac{3}{16}''$	60	2·00	120	1	7925	28	20	52	...	...	$15\frac{1}{2} \times 12\frac{1}{2}$	Conglomerate.
Michigan, Lake Superior and Phœnix..................	Atmospheric Stamp.......	270	16	120	....	...	....	$6\frac{2}{3}$	...	......	...	...	...	...	...	....	....
Brazil, Morro Velho.............	Cornish Pattern..	640	12	73	....	...	1·41	......	...	......	...	...	...	...	...	....	....
Australia, Clunes, Port Phillip company...........	"	800	8	75	....	...	3·30	......	...	......	...	...	...	...	...	....	....
Australia, Clunes, Port Phillip company.................	"	800	8	75	....	...	2·42	......	...	......	..	...	.. .	...	...	....	....
Thompson's Pulverizer (S. P. M. Tasker), Size B........	Centrifugal...	ball 180	...	230	No. 60	10	6 to $7\frac{1}{2}$	60	$\frac{1}{4}$	625	...	...	...	25	75	7×4	Very hard and tough Laurentian rock.
Thompson's Pulverizer (S. P. M. Tasker), Size C.........	"	120	...	300	No. 60	6	6	30	$\frac{1}{4}$	625	...	...	...	25	75	5×4	"
Thompson's Pulverizer (S. P. M. Tasker), Size D.........	"	70	...	400	No. 60	4	6	15	$\frac{1}{4}$	625	...	...	...	25	75	4×3	"

The ore receiver *W* and elevator *U* are not necessary when the rock breaker is placed on the floor above, and the broken ore fed directly into the hopper *T*, which is the most economical mode of feeding, and the plan recommended by the manufacturer.

A NEW METHOD OF DETERMINING PHOSPHORIC ACID.

By Henry Pemberton, Jr.

Read before the Chemical Section of the Franklin Institute, Feb. 7, 1882.

The process I am about to describe, and which I first tried in the summer of 1879 and have used since that time, consists in titrating phosphoric acid by direct precipitation, by means of a standard solution of molybdate of ammonia.

The principle is the same as that of Gay-Lussac's silver estimation, or Wildenstein's estimation of sulphuric acid by barium chloride; the standard solution is run in until further addition no longer causes a cloud, and the volume then read off.

Any one who has used ammonic molybdate for separating P_2O_5 in the usual gravimetric determination will at once see that the following obstacles will have to be overcome:

(1) The usual nitric acid solution of the molybdate is not stable, and is therefore unfitted to act as a standard solution, on account of the gradual separation of molybdic acid.

(2) The yellow precipitate does not separate completely until after the lapse of considerable time.

(3) A decided excess of the molybdate must be added to insure the complete precipitation of the P_2O_5.

(4) The precipitate has not always the same composition, being frequently mixed with free molybdic acid.

Two expedients have enabled me to overcome these difficulties: the use of an *aqueous* solution of ammonic molybdate, instead of the ordinary nitric acid solution—first advocated by John Parry (*Chem. News*, vol. xxv)—and the addition to the phosphate solution of a considerable quantity of nitrate of ammonia, in which the yellow precipitate is as good as insoluble—recommended by E. Richters (*Jour. Chem. Soc.*, 24, p. 157).

By so doing I have found that the standard solution is perfectly

stable, that the yellow precipitate falls immediately and completely, that a very small and definite excess ($\frac{1}{2}$ cc.) of the molybdate is required and that the ratio of molybdic trioxide to phosphoric anhydride is always the same.

Briefly stated, then, the process consists in adding nitrate of ammonia to the phosphate solution, using a limited quantity of nitric acid, and running in, from a burette, an aqueous solution of ammonic molybdate until, after the settling of the precipitate, the further addition of the standard solution leaves the liquid clear.

Starting out, as I did, completely in the dark, my first object was to get some general idea of the working of the proposed method. Therefore, without being exact in weights, I dissolved about 10 grammes of the molybdate in 100 cc. of water, and made a phosphate of soda solution of such strength that 50 cc. should equal 0·1000 gramme P_2O_5. 25 cc. of this phosphate solution was then treated with 2 cc. nitric acid, of 1·4 specific gravity, and with 10 grammes nitrate of ammonia. It was then heated, and the molybdate solution run in from a burette. The first drop caused an immediate precipitate. This was continued until, after settling of the yellow precipitate (which is quite rapid), further addition left the solution clear. I found, in three trials, that 25 cc. of the phosphate solution required 15·8 cc., 16·0 cc., 15·7 cc. of the molybdenum solution. This same was then repeated, but the final point was determined by filtering a little of the solution and testing it by the molybdate. 25 cc. required 15·5 cc., 15·3 cc., 15·5 cc., showing that in the first three trials, where the end of the reaction was shown by the settling of the precipitate, the point was somewhat overstepped. In all the following experiments, therefore, the end of the precipitation was determined by allowing the yellow salt to settle, filtering a little of the solution through a small filter, heating this clear filtrate, and testing it with more of the molybdate.

Nitric Acid.—Repeated above, using 5 cc. HNO_3, 1·4 sp. gr., in place of 2 cc. Required 16·0 cc., 16·0 cc., showing that a greater quantity of the molybdate is necessary in order to counteract the solvent action of the excess of nitric acid.

Ammonic Nitrate.—Proceeded as above, 2 cc. HNO_3, but used 20 grammes ammonic nitrate in place of 10 grammes, as before. Required 15·5 cc., 15·5 cc., proving that 10 grammes is sufficient when the total volume of the solution is not over 100 cc., or thereabout.

Dilution.—As above, 10 grammes NH_4NO_3, 2 cc. HNO_3, but dilu-

ted the solution so that the volume when finished equaled 130 cc., instead of from 50 to 70 cc., as above. Required 15·6 cc., showing that dilution, within moderate limits, does not affect the result.

Oxides of Iron and Alumina.—As above, but added 0·057 gramme Fe_2O_3, dissolved as nitrate, and 0·034 Al_2O_3, present as neutral tersulphate. Required 15·5 cc., proving that these sesquioxides—at least when present in above quantities—do not interfere.

The above were all preliminary trials, made merely to enable me to feel my way. Feeling encouraged by the results, I proceeded to make a more thorough examination.

10·085 grammes disodic hydric phosphate was dissolved in water and made up to 1000 cc. The amount of P_2O_5 in 50 cc. of this solution was then determined by precipitation and weighing as magnesic pyrophosphate, and also by evaporating, igniting and weighing as sodic pyrophosphate. I found in 50 cc.

By $Mg_2P_2O_7$ . .	0·1010	gramme	P_2O_5
" " . .	0·1009	"	"
" $Na_4P_2O_7$ . .	0·1012	"	"
Average = . .	0·10103	"	"

Showing that the salt before weighing had effloresced about 1 per cent.

93 grammes ammonic molybdate ($3(NH_4)_2O.7MoO_3.4H_2O$) were dissolved in water and made up to 1 litre, a slight cloudiness being removed by addition of a few drops of ammonic hydrate.

50 cc. of the phosphate of soda solution was then measured with a beaker, treated with 10 grammes NH_4NO_3 and with one cc. HNO_3, 1·40 sp. gr., and then warmed. Ammonic molybdate was then run in, but not a trace of a precipitate formed; but on adding another cc. of nitric acid a dense precipitate immediately formed. After adding still a third cc. of nitric acid 32·9 cc. of the molybdate were required for entire precipitation. Using, therefore, 10 grammes NH_4NO_3, 2 cc. HNO_3, 1·4 sp. gr., and titrating with the solution of 93 grammes molybdate to the litre, I found that 50 cc. P_2O_5 solution required, when the volume at the end was

$$115 \text{ cc.,} \quad . \quad . \quad \left.\begin{array}{l} 32{\cdot}5 \text{ cc.} \\ 32{\cdot}8 \text{ cc.} \\ 32{\cdot}7 \text{ cc.} \end{array}\right\} \text{Mean} = 32{\cdot}70 \text{ cc.}$$

When the volume at end was

60 cc. to 70 cc., . $\left.\begin{matrix} 32{\cdot}8 \text{ cc.} \\ 32{\cdot}9 \text{ cc.} \end{matrix}\right\}$ Mean = 32·85 cc.

Again, when volume = 120 cc.,

$\left.\begin{matrix} 33{\cdot}0 \text{ cc.} \\ 32{\cdot}8 \text{ cc.} \end{matrix}\right\}$ Mean = 32·90 cc.

The means, therefore, were: 32·70 cc.
32·85 cc.
32·90 cc.

General mean = 32·82 cc. to precipitate 0·10103 grm. P_2O_5. Therefore 0·1000 gramme P_2O_5 would require 32·48 cc.

It is well known that in the usual way of precipitating this yellow salt, where a large quantity of nitric acid is present, a considerable excess of the molybdate is required. Having this in view, I tried the following experiment. Since 50 cc. of the P_2O_5 solution require, as above, 32·82 cc. molybdate, 5 cc. should require one-tenth of this, or 3·28 cc. I found, however, that 5 cc. required, in two trials, 3·7 cc. and 3·7 cc., an excess of 0·42 cc. Again, 1·5 cc. P_2O_5 solution (= 3 per cent. of 50 cc.) should require 3 per cent. of 32·82 cc. = 0·98 cc. By experiment 1·45 cc. were required, an excess of 0·47 cc. As it is not required to differentiate more finely than to the $\frac{1}{10}$ cc., it appears that 0·5 cc. excess is required, first to neutralize the slight solvent power of the HNO_3 present, and secondly to precipitate the small quantity of P_2O_5 held back in the pores of the filter paper in the final testing. Subtracting, therefore, this 0·5 cc., we find that 0·10103 gramme P_2O_5 require 32·82 cc. — 0·5 cc. = 32·32 cc. Therefore 0·1000 gramme P_2O_5 require 32·00 cc. molybdate.

Ratio of MoO_3 *to* P_2O_5.—Ammonic molybdate contains, when perfectly pure, 81·55 per cent. MoO_3. One determination of the sample I used (of German manufacture) gave me, by Chatard's method, 81·27 per cent. MoO_3. Using the theoretical figures, a litre of molybdate solution containing 93 grammes will contain 75·8415 grammes MoO_3. 32 cc., therefore, will contain 2·4269 grammes MoO_3, this representing the amount required to precipitate 0·1000 gramme P_2O_5. Therefore $MoO_3 : P_2O_5 :: 24{\cdot}269 : 1$. This represents the ratio *by weight*.

Dividing by the molecular weight of each (144 and 142 respec-

tively) we get $23\frac{93}{100}$ molecules* of MoO_3 to 1 molecule P_2O_5, or practically 24 to 1.

This is precisely the figure established by Finkner, and still more recently by Dr. Gibbs in his investigation into the phosphomolybdates, just published in a recent number of the *American Chemical Journal*.

The agreement of these results, obtained in entirely different ways (those of Finkner and Gibbs by analysis, mine by synthesis) prove what I previously asserted in regard to the constancy and reliability of results by this process. In the ordinary gravimetric determination of P_2O_5, where the latter is separated by the nitric acid solution of the molybdate, the solution has to stand in the heat for several hours and in the presence of a decided excess of the reagent. It is, therefore, impossible to guarantee the absence of admixed molybdic acid, and almost every chemist analyzing the per cent. of P_2O_5 in the yellow salt obtained a different result. It is, accordingly, this fact that has prevented the universal adoption of the yellow precipitate as a basis upon which to calculate the phosphoric acid.

I have, therefore, gone somewhat minutely into this question, to prove that these sources of error do not exist in this volumetric process.

Action of Nitric Acid.—I found that 50 cc. of the P_2O_5-solution require

(With	1	cc. HNO_3	1·4 sp. gr.—			no precipitate)
"	2	"	"	"	32·8 cc.	
"	3	"	"	"	32·9 "	
"	$5\frac{1}{2}$	"	"	"	33·2 "	
"	$10\frac{1}{2}$	"	"	"	33·8 "	—is not enough.

Action of Chlorides.—10 cc. P_2O_5 solution should require 6·46 cc. With 5 grammes NH_4Cl added required in two trials 6·60 and 6·65 cc. Again, 10 cc. P_2O_5 solution with 1·17 gramme $CaCl^2$ added require 6·55 cc. Again, 5 cc. of another P_2O_5 solution which should require 4·90 cc., when treated with 1 cc. HNO_3 and 1 cc. strong HCl requires 4·90 cc. Hence chlorides do not seem to have any appreciable effect.

Temperature.—The solution containing the phosphate has to be quite hot; a steam should play upon the surface of the liquid. One

*Even if calculated upon the basis of 81·27 per cent. MoO_3 in the molybdate (as per my analysis), the result is practically the same, viz.: $23\frac{85}{100}$ MoO_3 to P_2O_5.

determination showed 136°Fahr.; this should certainly be regarded as the minimum. A solution of known strength, to which about 90 per cent. of the molybdate required had been added, and which had been kept only slightly warm, was filtered, and the filtrate heated. A decided yellow precipitate at once formed. From 140° to 160°Fahr., or even somewhat higher, appears to be about the correct temperature.

Action of Silicic Acid.—Halloysite was decomposed with sulphuric acid, the silica filtered, washed, and boiled repeatedly with HCl. Again washed, dried and ignited. 0·1725 gramme of this ignited silica was fused with Na_2CO_3, dissolved in water, neutralized with HNO_3 treated with 10 cc., P_2O_5 solution, and then titrated. It should have required 6·45 cc. molybdate, but did require 7·5 cc., and even when 8·7 cc. had been added, gave with more molybdate, at first a yellow color, and after standing, a faint cloud. Silicic acid therefore interferes.

Action of Organic Matter.—The material used for this purpose is what is known in the trade as "azotine" or "ammonite." Refuse from slaughter-houses, dead animals, etc., are subjected to a treatment with hot benzine, by which the fat is extracted. The residue consists of a certain amount of bone with every variety of organic matter except the fat, and as it comes into the market in a fine dry powder, is well adapted to examination, weighing, etc. It was with particular reference to the analysis of fertilizers that I selected this substance as a typical form of organic matter likely to be found in these.

Before examining this, there are a few points to be noticed. First, Mulder has shown (*Chem. Gazette*, vii., p. 62) that higher results are obtained by treating organic compounds containing phosphorus with HNO_3 than are obtained by dissolving in HCl. He finds that the excess of P, oxidized by HNO_3 over the quantity dissolved by HCl, and calculated into phosphoric acid, to be, with albumen, 0·99 per cent., albumen in blood, 0·76 per cent., fibrin, 0·76. It has not been established that phosphorus, in organic combination, is of any value as plant-food. In fact, from the nature of the case, it never will be decided.

Secondly. Although shown by Kastner to be the case over half a century ago, it is, in all probability, not generally known that the phosphoric acid in calcined bones exists not as ortho-phosphoric acid, but chiefly as pyro- or meta-phosphoric acid; and this, too, in spite of the fact that three atoms of base are present.

Thirdly. In igniting the azotine, to burn off the organic matter,

the small quantity of dirt, sand, etc., always present, yields a certain amount of soluble silicic acid, on subsequent treatment with acid, and this will interfere, unless the solution is evaporated to dryness.

The following are the analyses of several brands of this azotine: By "volumetric" is meant that the determination is made by titration with ammonic molybdate. By MoO_3 and MgO that the usual gravimetric method was used.

Volumetric. Ignited azotine, evaporated to dryness,	14·19	per cent. P_2O_5.
" " " not "	14·50	" "
" " " not " (2d analysis)	14·64	" "

showing the action of silica.

Volumetric. Raw azotine (not ignited) dissolved in HNO_3, evaporated twice, . . . 15·05 per cent.

showing the action of oxidizing agents.

Another sample gave:

MoO_3 and MgO., raw azotine, HCl solution,	2·87	per cent. P_2O_5.
Volumetric " " " "	2·73	" "
" " (repeated) . .	2·67	" "
" Ignited, evaporated to dryness,	2·90	" "
" Same repeated, . . .	3·06	" "
" Ignited (not evap., action of SiO_2),	3·20	" "

Another sample:

$MoO_3 + MgO$ raw azotine, . .	4·45	per cent. P_2O_5
Volumetric " . .	4·57	"
" " $HNO_3 + KClO_3$.	5·21	"
" same repeated, . .	5·60	"
" Ignited but not evaporated, .	4·84	"
" same repeated, . .	4·91	"

I now made a mixture of acid phosphate of lime from South Carolina phosphate rock and sulphuric acid, containing (about)

9	per cent. soluble	P_2O_5
$3\frac{1}{2}$	" reverted	"
$2\frac{1}{2}$	" insoluble	"
15	per cent. total	"

This was mixed so as to contain in 100 parts of the above acid

Phosphate, . . .	79 parts
Azotine, ...	16 "
Potassium chloride, . .	5 "
	100 "

and this mixture, after being finely ground and averaged, was analyzed, as follows:

By $MoO_3 + MgO$ (not ignited, . .	13·32	per cent.	P_2O_5
Volumetric, ignited, evaporated to dryness,	13·25	"	"
(Showing no loss from formation of pyrophosphate).			
Volumetric, not ignited, HCl solution evap'd,	13·11	"	"
	13·07	"	"
	13·24	"	"
Volumetric " " *not* evaporated,	14·03	"	"

Again, the above mixture was leached, filtrate not measured, but 25 cc. (= about 0·8 gramme) taken for each trial.

By $MoO_3 + MgO$ (evaporated to dryness with HCl)	70·7	mgr.	P_2O_5
Volumetric, " " "	69·3	"	"
" not evaporated, . .	71·1	"	"

From the above it appears that by dissolving in HNO_3 and evaporating to dryness, the results are above the truth; by dissolving in HCl, the result may be 0·1 per cent. to 0·2 per cent. low; by igniting and not evaporating, the silica will interfere; but that by igniting and evaporating to dryness the results are correct, or vary only within the limits of instrumental errors.

I have observed no difficulty in working with pyrophosphates, provided that the ignition be carried on at not too high a temperature, and the evaporation with nitric acid be repeated.

Citric, tartaric and oxalic acids interfere and must not be present. When the oxalic acid is oxidized by permanganate, the yellow precipitate falls immediately.

The following is a condensed description of the modus operandi in performing the analysis.

89·5430 grammes ordinary ammonic molybdate are put into a litre flask, water added and the whole shaken until the salt dissolves. If a cloudiness is left in the liquid, a little ammonic hydrate is added. A small excess of this is not objectionable. The flask is then filled to the mark.

The above weight of the molybdate is calculated so as to give MoO_3 to P_2O_5 exactly as 24:1. Each cc. precipitates 3 milligrammes P_2O_5. It differs from the figure obtained empirically by an amount equal to only 0·0003 gramme P_2O_5 in a determination of 0·1000 gramme P_2O_5.

The phosphate to be examined is then taken in quantity containing not over 0·1000 gramme P_2O_5 or 0·1500 gramme at the utmost. If

silica is present the solution is evaporated to dryness. In presence of organic matter ignite gently and evaporate to dryness twice with HNO_3. There is no advantage in filtering off the SiO_2. The solution is transferred to a beaker of 100 to 125 cc., using as little water as possible to prevent unnecessary dilution, and is just neutralized with NH_4HO, *i. e.*, until a slight precipitate is formed.

If much iron is present the ammonia is added until the yellow color *begins* to change to a darker shade. 2 cc. of nitric acid are added. Care must be taken that the sp. gr. of the acid is not less than 1·400, otherwise more must be added. 10 grammes of granular nitrate of ammonia are now added. After a little experience the quantity can be judged with sufficient accuracy by the eye without the trouble of weighing. The solution is now heated to 140°F. or over and the molybdate solution run in (most conveniently from a Gay-Lussac burette), meanwhile stirring the liquid. The beaker is now left undisturbed for about a minute on the water-bath or hot plate and the precipitate settles, leaving the supernatant liquid not clear but containing widely disseminated particles, in which the yellow cloud can easily be seen on the further addition of the molybdate. This addition is continued as long as the precipitate is thick and of a deep color. But as soon as it becomes rather faint and thin, a little of the solution, about 2 to 3 cc., after settling of the precipitate, is filtered through a small filter (not over 5 cm. in diameter) into a very small beaker, and this is heated on a hot plate and 4 or 5 drops of the molybdate added. If a precipitate is produced the whole is poured back into the large beaker and a further addition of the molybdate (1, 2 or 3 cc.) added, according to the quantity of the precipitate in the small beaker. After stirring and settling, another small quantity is filtered through the small filter and again tested. If the mark has been overstepped and too much molybdate added a measured quantity of P_2O_5 solution of known strength is added, and the corresponding amount of P_2O_5 deducted. In filtering through the small filter the liquid held sometimes in the neck of the funnel must be allowed to run out.

I generally check my results by adding a cc. of standard P_2O_5 solution, and then again testing. This can be repeated as often as desired. The portion that *last* produces a cloud, is the final point. From this is substracted 0·5 cc. (for neutralizing the solvent action of the HNO_3, as above explained), and the remainder multiplied by 3 gives the weight of P_2O_5 in milligrammes.

One decigramme of P_2O_5 gives about $2\frac{3}{4}$ grammes of the yellow precipitate, and the accuracy of the process is largely due to this smallness of the percentage of the P_2O_5.

The ammonic molybdate is now prepared in a state of great purity. Several samples that I have bought did not vary in strength to any appreciable extent. It may, possibly, contain a trace of phosphoric acid which, however, does not affect the result, since it will have the same weakening action in the standardizing tests that it has in the actual analysis.

I have used this process entirely in determining phosphoric acid in materials containing it in quantity, *e. g.*, apatite phosphate rock, fertilizers, etc.

It is *not* adapted to the direct determination of minute quantities of phosphorus in iron or iron ores. At least 5 grammes of the ore must be taken, and in the concentrated solution formed by this quantity of the iron salt and the nitrate of ammonia, the precipitate settles slowly on account of the density, and is seen with difficulty because of the depth of color. Moreover, I have observed that a solution of ferric nitrate shows a somewhat peculiar behavior on addition of ammonic molybdate; molybdic acid at once separates in a curdy precipitate which redissolves on stirring. This reaction does not take place when iron is absent. Ferric nitrate, moreover, has the effect of retarding the precipitation somewhat, and it, therefore, is more difficult to see how the precipitation is proceeding, when Fe_2O_3 is present in quantities exceeding a decigramme or so. These properties are peculiar to iron oxide only, and not to alumina.

In working with unknown quantities the titration requires about an hour for its performance. Of all the forms of volumetric analysis, that one, in which the final point is determined by the cessation of the precipitation is the least desirable. And were it not that the ordinary method requires a day rather than an hour (including at least two precipitations of the magnesia salt), the process of direct precipitation above described would hardly be able to hold its own in comparison.

I have obtained very sharp and accurate results by determining the amount of the yellow precipitate, (formed as above, after thorough washing) by means of a standard solution of caustic alkali, using litmus as an indicator; a description of which I hope to present in a future paper.

I mention it here simply to place the fact on record.

THE ANALYSIS OF IRON ORES CONTAINING BOTH PHOSPHORIC AND TITANIC ACIDS.

By THOMAS M. DROWN, M.D., and P. W. SHIMER, M.E., Easton, Pa.

Read at the Meeting of the American Institute of Mining Engineers, Oct., 1881.

The precipitation of phosphoric with titanic acid by boiling an iron solution which had been reduced to the ferrous condition by sulphuretted hydrogen or sulphurous acid was first noticed by E. H. Bogardus in 1874.* Since that time, as far as we are aware, not much has been published on the relation of these two acids to each other, and to silicic acid in the ordinary course of analysis of iron ores. The following investigation may perhaps aid in clearing up some of the obscure points in the analysis of titaniferous ores.

THE DETERMINATION OF PHOSPHORUS.

From two to five grammes of the finely powdered ore are weighed into a beaker and treated with abont 50 cc. of hydrochloric acid (sp. gr. 1·12), evaporated to dryness, and heated in an air-bath for an hour to 110° to 120°C. To the dry mass are added 50 cc. of hydrochloric acid (1·12), and the solution filtered off from the insoluble residue. On washing this residue with water the filtrate often runs through turbid. This can be avoided by washing with dilute nitric acid, or, better, with an acid solution of ammonium nitrate. The filtrate contains the greater part of the phosphoric acid, but the residue may contain a notable amount.

Treatment of the Residue.—Fuse the residue with sodium carbonate and extract with water. Sodium phosphate and silicate go into solution and sodium titanate remains insoluble. Filter, acidify the filtrate with nitric acid, evaporate to dryness, moisten with nitric acid, and dissolve in water. Filter from the silica, concentrate the filtrate, neutralize nearly with ammonia, and precipitate with ammonium molybdate. This is the best method of separating the phosphorus from the insoluble residue. The bulk of the phosphorus may, however, be extracted from the moist residue by washing with ammonia.

Treatment of the Filtrate.—Evaporate to a small bulk, and add

* *American Journal of Science*, III, 8, p. 334.

enough nitric acid to drive off all the hydrochloric acid on evaporation. If the concentrated solution is clear, add ammonia until a slight permanent precipitate is formed; redissolve this in a few drops of nitric acid, and add ammonium molybdate solution.

In the ores of which we are speaking, a precipitate generally separates on evaporating to a small bulk. The addition of more nitric acid with continued heat often redissolves this; in this case, the evaporation must not be carried too far, or the substance will again precipitate. This precipitate contains phosphoric acid and titanic acid. If it is impossible to get it into solution in nitric acid, it must be filtered off and washed with ammonium nitrate solution. It is then ignited, fused with sodium carbonate, extracted with water, and the filtrate, after acidifying with nitric acid, precipitated with molybdate solution.

After the addition of the ammonium molybdate to the main solution, as mentioned above, it is heated rather hot, say from 50° to 70°C., for half an hour, with frequent vigorous stirring. The precipitate is usually allowed to stand over night, but if filtered within two hours, there will be no appreciable amount of phosphorus unprecipitated. The yellow precipitate is filtered off and washed well with a mixture of 325 cc. of nitric acid (sp. gr. 1·2), 100 cc. of ammonium hydrate (sp. gr. 0·96), and 100 cc. of water. It is then dissolved upon the filter in dilute ammonia. The solution will probably run through turbid, and a gelatinous residue will remain in the filter. The solution is heated for some time and filtered, and this residue, which contains both phosphoric and titanic acid, is treated, together with the gelatinous residue insoluble in ammonia, with nitric acid, and the resulting solution precipitated with ammonium molybdate. By heating and stirring, the phosphoric acid can be completely precipitated in an hour, so that it will not retard the analysis materially. The solution of this yellow precipitate in ammonia is to be added to the main ammoniacal solution, and magnesia mixture added with the usual precautions. By active stirring after the addition of magnesia mixture the complete precipitation of the phosphoric acid may be effected in an hour or two.* In the analysis of an ore containing 4·74 per cent. of phosphoric acid (mostly as apatite) and 0·65 per cent. of titanic acid, the phosphoric acid was found (in duplicate analyses) as follows:

* The action of stirring or other agitation in hastening precipitation, although well known, is not, I think, as often made use of in analysis as it might be.

	I.	II.
Phosphoric acid in the hydrochloric acid solution, .	4·370	4·330
Phosphoric acid in the residue insoluble in hydrochloric acid, ...	0·280	0·390
Phosphoric acid in the precipitate which separated from the solution of the yellow precipitate in ammonium hydrate, . .	0·016	0·027
Total, ...	4·666	4·747

Determination of the Titanic Acid.

One to two grammes of the finely powdered ore are weighed into a large platinum crucible. Potassium bisulphate* to the amount of 12 to 15 times the weight of the ore is next weighed out in another vessel. Mix the ore in the bottom of the crucible with about one-quarter of the bisulphate, and fuse until the excess of sulphuric acid is nearly all driven off. During the progress of the fusion, the lid must be lifted a very little at short intervals, in order to watch the state of the fusion. It should not be allowed to rise above two-thirds the height of the crucible. Add now another quarter of the bisulphate, and heat again as before, until nearly all the excess of sulphuric acid is driven off. Then add the remaining half of the bisulphate, and heat until the whole mass is in quiet fusion. Too much sulphuric acid should not be driven off at this stage, or the subsequent solution in water will be retarded. The fused mass may be poured out into a large platinum dish, or it may be removed from the crucible in one lump by inserting a stout piece of platinum wire while still soft, and allowing the mass to solidify about it. A gentle heat on the outside of the crucible will quickly loosen the mass, which may now be lifted out easily. The former method is preferable, because of the thinness of the mass and its readier solubility.

When the mass has become cold, it is dissolved in plenty of cold

* In order to make a successful determination of titanic acid, it is necessary to have good potassium bisulphate. This can seldom be bought in a condition fit for use. It usually contains water; sometimes an excess of sulphuric acid; it also usually contains an insoluble siliceous residue. To prepare it for use, it is dissolved in water and filtered, the solution evaporated to dryness, and fused until all the water is driven off and the mass is in quiet fusion. It is sometimes necessary to drive off some sulphuric acid. It is then powdered for use. Bisulphate thus prepared will not mount readily in the crucible, and a quiet fusion at a red heat can be obtained.

water. This usually requires at least twelve hours. When it is evident that all has dissolved but silicates,* filter into a large beaker. This insoluble residue should, after ignition, be again fused with bisulphate and tested as below for titanic acid. To the main solution we add sodium carbonate solution until a slight permanent precipitate is obtained, then 3 to 4 cc. of sulphuric acid of 1·23 sp. gr. This redissolves the slight precipitate and makes the solution sufficiently acid.

Add now sulphurous acid in excess, and dilute largely with water (1 to 1·5 litre); cover with a watch-glass, and boil about two hours, adding sulphurous acid solution and water as the evaporation goes on. The titanic acid is precipitated, and with it phosphoric acid and oxide of iron. Filter hot (best done by means of a siphon), and wash with hot water. This precipitate of titanic acid and phosphoric acid is not finely granular like that of pure titanic acid, but is flocculent, and shows no tendency to run through even a very porous filter. It is dried, ignited, and weighed. In spite of the fact that it contains a very notable amount of iron, it is usually white after ignition. It is fused with sodium carbonate and extracted with water. Sodium titanate and oxide of iron remain insoluble. while sodium phosphate goes into solution. The residue is dissolved in sulphuric acid (sp. gr. 1·23), filtered, neutralized with sodium carbonate, 2 to 3 cc. of sulphuric acid added, and then sulphurous acid as above. The titanic acid precipitated from this solution is free from phosphoric acid and iron.

If, instead of fusing the first precipitate of titanic acid with sodium carbonate, it is re-fused with potassium bisulphate, there will remain on treatment with cold water an insoluble residue containing titanic acid and phosphoric acid.

The following analytical resulte will illustrats the foregoing description:

	I.	II.
First precipitate of titanic acid containing phosphoric acid and iron (in duplicate), per cent., .	3·18	2·40

No. 1 was fused with sodium carbonate and treated with water as above. It consisted of:

* In ores containing lime, calcium sulphate is often found in this insoluble residue.

Titanic acid,	0·65
Phosphoric acid,	1·60
Sesquioxide of iron,	·84
Loss,	·09
	3·18

No. 2 was fused with potassium bisulphate, and gave:

Residue insoluble in cold water,	1·83
Precipitate by boiling the solution,	·34
Sesquioxide of iron, by difference,	·23
	2·40

The titanic acid precipitated by boiling (·34) contained both phosphoric acid and iron.

The residue insoluble in cold water (1·83) was fused with sodium carbonate as described above; it gave:

Phosphoric acid,	·96
Titanic acid,	·42
Sesquioxide of iron, by difference,	·45
	1·83

The precipitate by boiling (·34), similarly treated, gave:

Phosphoric acid,	·05
Titanic acid,	·12
Sesquioxide of iron, by difference,	·17
	·34

The complete analysis of the original precipitate (2·40) thus shows:

Titanic acid,	·54
Phosphoric acid,	1·01
Sesquioxide of iron, by difference,	·85
	2·40

The titanic acid is here doubtless ·10 per cent. too low, owing to the many fusions and precipitations to which it was subjected.

Determination of Iron.

If the ore contains less than one per cent. of titanic acid, no appreciable error will result from neglecting it. If it contains more than this, the iron must be determined in the filtrate from the titanic acid.

The first precipitation of titanic acid contains iron. This is separated by the sodium carbonate fusion, and may be added to the main solution after separation of the titanic acid. The iron is then determined by reduction with zinc and titration with permanganate.

Determination of Silica and Alumina.

When an iron ore containing phosphoric and titanic acids is treated for silica by the usual method (fusion with sodium carbonate, solution in dilute hydrochloric acid, evaporation to dryness, and separation of silica at 110°C., solution in hydrochloric acid and water, and filtration from the insoluble residue), the siliceous residue consists of silica, titanic acid, phosphoric acid, and iron. In the case of an ore containing 3·50 per cent. of silica, this residue (which, in spite of the iron in it, is white after ignition) amounted to 6·11 per cent. The presence of phosphoric acid and iron with the silica of course renders worthless the estimation of alumina by difference.

Before speaking of the determination of the silica, we will consider how we may get the phosphoric acid and iron into the main solution where they belong. The insoluble residue (containing silica, titanic acid, phosphoric acid, and iron) is fused with sodium carbonate, and extracted with water. Sodium phosphate and silicate dissolve, and sodium titanate and ferric oxide remain behind. Acidify the filtrate with hydrochloric acid, and evaporate to dryness; take up with hydrochloric acid and water, and filter off the silica; add the filtrate to the solution to be precipitated by sodium acetate. Dissolve the residue insoluble in water (containing the sodium titanate and ferric oxide) in sulphuric acid, and separate the titanic acid from the iron by boiling, as usual. Filter from the titanic acid, and add bromine-water to the filtrate, in order to oxidize the iron, boil, and precipitate the iron with ammonia. Filter and weigh it with the precipitate of iron, alumina, and phosphoric acid, separated as basic acetate.

Some titanic acid may go into the filtrate, which is to be precipitated by sodium acetate. In this case it will contaminate the precipitate of iron, alumina, and phosphoric acid. It is therefore necessary, after this precipitate has been weighed, to grind it in an agate mortar, and weigh out accurately as much of it as possible, fuse with potassium bisulphate, and determine the titanic acid in it by boiling, etc. The titanic acid thus found is to be deducted from the weight of the original

precipitate. There will not in all cases be titanic acid in this precipitate, but it is not safe to omit testing for it.

The silica may also be determined by fusing the residue from the second bisulphate fusion for titanic acid with sodium carbonate, and separating the silica as usual. Or it may be determined by fusing 1 to 1·5 grams of the ore with sodium carbonate, dissolving in hydrochloric acid, and adding an excess (50 cc.) of sulphuric acid (1·23), and evaporating until all the hydrochloric acid is driven off. This renders the silica insoluble. By now dissolving the ferric sulphate in a large excess of hydrochloric acid by aid of heat, everything goes into solution but the silica. When this point is reached, it is known by the absence of everything but transparent gelatinous silica floating in flocks in the clear solution. Calcium sulphate may contaminate the silica, if the ore contains much lime; but it does not look like gelatinous silica, and dissolves on dilution with water.

The following determinations illustrate the foregoing description:

	I.	II.
Insoluble in hydrochloric acid,	6·11 per cent.	5·38 per cent.

Fused with sodium carbonate and extracted with water, solution contained:

I.		II.	
Silica, . .	3·31	Silica, . .	3·63
Phosphoric acid,	1·03	Phosphoric acid,	·71

Residue contained:

I.		II.	
Titanic acid, . .	·65	Titanic acid. . .	·65
Sesquioxide of iron,	1·53	Sesquioxide of iron,	·58

Totals.

	I.	II.
Silica, ...	3·31	3·63
Phosphoric acid, . .	1·03	·71
Titanic acid, . . .	·65	·65
Sesquioxide of iron, . .	1·33	·58
	6·32	5·57

	I.	II.	III.
Silica made insoluble by sulphuric acid, .	3·40	3·48	3·54
Silica from residue insoluble in bisulphate,	3·70	3·74	......
Residue insoluble in bisulphate, .	4·91	5·03	......

Mr. JULIAN KENNEDY, of Pittsburg, said that the slow solution of the potassium bisulphate, after fusion, could be avoided by the following procedure. When the fusion is complete enough concentrated sulphuric acid is added so that the resulting mass shall be pasty on cooling. This mass may then be dissolved promptly by aid of heat, the excess of sulphuric acid preventing the separation of titanic acid. The excess of acid is subsequently neutralized when the titanic acid is to be precipitated by boiling.

THE CONDITION OF SULPHUR IN COAL, AND ITS RELATIONS TO COKING.

By THOMAS M. DROWN, Easton, Pa.

Read at the Meeting of the American Institute of Mining Engineers, Feb., 1881.

At the meeting of the Institute in New York, in February, 1880,* I described a process of determining sulphur in metallic sulphides, with especial reference to the determination of pyrites in coal. The process, as then described, is as follows: A solution of sodium hydrate, of 1·25 specific gravity, is saturated with bromine. If an excess of bromine is used it must be neutralized by the addition of a little more sodium hydrate. The pulverized mineral or coal is moistened with 25 cc. of this solution and heated, then hydrochloric acid is added cautiously to just acid reaction. This operation is repeated with another 25 cc. of the alkaline solution, and again rendered acid. The mixture should be kept hot. The contents of the beaker or dish are then evaporated to dryness, to separate silica, and taken up by dilute hydrochloric acid. The sulphuric acid is precipitated, with the usual precautions, by barium chloride. In the paper referred to determinations by this process of sulphur in coal were given, which, although agreeing closely with one another, yet fell far short of the total sulphur in the coal, and the inference was that the sulphur not oxidized by the treatment with the bromine solution was an organic constituent of the coal, and could only be determined by a process which would oxidize the coal completely.

* Transactions of the American Institute of Mining Engineers, vol. viii, p. 569.

I am now able to give further results of the application of this process to the analysis of coal and coke. The object in view in this investigation was to determine, if possible, the effect of coking on the amount and condition of sulphur in the coal. Although the results in this regard are not as decisive as could be wished, yet many interesting facts have been noticed in the course of the work.

The coals used were from Pennsylvania and Virginia, and will be simply designated by letters. Two series of experiments were made. In the first the coke was made in the laboratory, in platinum crucibles; and in the second, "industrial coke," made in beehive ovens, was used.

In the first series the total sulphur was determined, by way of control, by fusion with alkaline carbonates and nitre; and in the second by Eschka's method of heating the coal with calcined magnesia and sodium carbonate.

First Series.

Coal A.

Proximate Analysis.		Analysis of Ash.	
Moisture,	0·75	Silica,	47·74
Volatile matters,	15·35	Alumina and oxide of iron,	34·17
Fixed carbon,	66·10	Lime,	7·61
Ash,	17·80	Magnesia,	0·98
		Sulphuric acid,	5·30
	100·00		95·80

The small quantity of ash used for this analysis is doubtless the cause of the imperfect result.

Sulphur Determinations in Coal A.

I. By Bromine Mixture.	II. In residue from I by combustion in oxygen, and absorption by solution of potassium permanganate.	III. In Ash from II by fusion with sodium carbonate.	IV. Total, sum of I, II and III.	V. By direct combustion of coal in oxygen, and absorption by solution of potassium permanganate.	VI. In Ash from V by fusion with sodium carbonate.	VII. Total, sum of V and VI.	VIII. Total by fusion with sodium carbonate and nitrate.
1·660	0·640	0·040	*2·340*	1·983	0·203	*2·186*	*1·940*
1·640	0·520	0·043	*2·203*	1·768	0·329	*2·097*	*1·980*
1·670	0·563	0·026	*2·259*	1·942	0·212	*2·154*	

SULPHUR DETERMINATIONS IN COKE *A*.

1·073	0·747	0·065	*1·885*	1·287	0·477	*1·764*
1·180	0·666	0·062	*1·908*	1·290	0·494	*1·784*
1·180	0·627	0·045	*1·852*			

Coal B.

Proximate Analysis.		Analysis of Ash.	
Moisture,	3·48	Silica,	28·89
Volatile matters,	25·25	Alumina and oxide of iron,	65·92
Fixed carbon,	66·63	Lime,	2·49
Ash,	4·34	Magnesia,	0·57
		Sulphuric acid,	2·02
	100·00		99·89

SULPHUR DETERMINATIONS IN COAL *B*.

I. By Bromine Mixture.	II. In residue from I by combustion in oxygen, and absorption by solution of potassium permanganate.	III. In Ash from II by fusion with sodium carbonate.	IV. Total, sum of I, II and III.	V. By direct combustion of coal in oxygen, and absorption by solution of potassium permanganate.	VI. In Ash from V by fusion with sodium carbonate.	VII. Total, sum of V and VI.	VIII. Total of fusion with sodium carbonate and nitrate.
0·041	0·450	0·031	*0·522*	0·431	0·058	*0·489*	*0·474*
0·035	0·464	0·037	*0·536*	0·461	0·035	*0·496*	*0·473*
				0·454	0·053	*0·507*	

SULPHUR DETERMINATIONS IN COKE *B*.

0·034	0·406	0·060	*0·500*	0·429	0·087	*0·516*	*0·495*
0·056	0·400	0·063	*0·519*	0·441	0·080	*0·521*	*0·536*

Coal C.

Proximate Analysis.		Analysis of Ash.	
Moisture,	1·16	Silica,	60·94
Volatile matters,	33·08	Alumina and oxide of iron,	32·86
Fixed carbon,	61·81	Lime,	1·75
Ash,	3·95	Magnesia,	0·10
		Sulphuric acid,	2·28
	100·00		97·93

SULPHUR DETERMINATIONS IN COAL *C*.

I. By Bromine Mixture.	II. In residue from I by combustion in oxygen, and absorption by solution of potassium permanganate.	III. In Ash from II by fusion with sodium carbonate.	IV. Total, sum of I, II and III.	V. By direct combustion of coal in oxygen, and absorption by solution of potassium permanganate.	VI. In Ash from V by fusion with sodium carbonate.	VII. Total, sum of V and VI.	VIII. Total by fusion with sodium carbonate and nitrate.
0·127	0·647	0·028	*0·802*	0·693	0·036	*0·729*	*0·766*
0·139	0·631	0·022	*0·792*	0·701	0·030	*0·731*	*0·712*
				0·762	0·035	*0·797*	

SULPHUR DETERMINATIONS IN COKE *C*.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.
0·041	0·547	0·026	*0·614*	0·583	0·033	*0·616*	*0·640*
0·018	0·582	0·028	*0·628*	0·605	0·034	*0·639*	*0·650*

It has been recently stated by Mixter* that bromine water, or a solution of bromine in hydrochloric acid, fails to oxidize all the sulphur dioxide produced by the combustion of coal, and that the vapors should be carried into a large bottle containing bromine vapors before they are allowed to escape. I have found, also, that a final large bromine bottle collects a very small amount of sulphuric acid after the vapors have passed through a solution of potassium permanganate. A coal containing 0·721 per cent. of sulphur gave 0·009 per cent in the large bromine bottle, and another coal containing 0·605 per cent. gave 0·024 per cent. In the following experiments the large bromine bottle was used, and the sulphur given as absorbed by permanganate solution includes the small amount found in the bromine bottle. As stated in a previous paper, I much prefer potassium permanganate to bromine for the oxidation of sulphur dioxide or sulphuretted hydrogen.

In the combustion of bituminous coals in oxygen explosions frequently occur. These may be avoided by simply diluting the oxygen with atmospheric air to the extent of equal volumes. The coal or coke can be best ignited in the tube in the following manner. The platinum boat containing the coal is placed just within the tube, which

* *American Chemical Journal*, ii, 396.

is then filled with oxygen. The cork is then removed, and a glowing splinter of charcoal placed in the end of the boat, which is quickly pushed into the middle of the tube. The flow of oxygen is at once resumed, and the coal continues to glow until it is all consumed. The gas in the combustion furnace is kept turned low until the coal is nearly consumed, when it is turned on to a good red heat.

In the foregoing experiments the coke was made in platinum crucibles over a Bunsen burner. To test the effect of coking on an industrial scale, I had samples taken of the coal, which was put into an oven, and of the coke which came out. This was not done under my supervision, and consequently some uncertainty exists as to the thoroughness of the sampling. The following are the results obtained on three samples of coal and the corresponding coke made in ovens.

The total sulphur was directly determined in these coals and cokes by Eschka's method of heating with calcined magnesia and sodium carbonate, and oxidizing the solution in water by bromine. This is much to be preferred, in regard to simplicity and accuracy, to fusion with alkaline carbonates and nitre.

Second Series.

Coal E.

Proximate Analysis.

Volatile matters (including moisture), .	24·25
Fixed carbon, . . .	70·51
Ash, ...	5·24
	100·00
Ash in coke, ...	5·41

The ash determinations in this coal and coke indicate imperfect sampling.

Sulphur Determinations in Coal *E.*

I. By Bromine Mixture.	II. In residue from I by combustion in oxygen.	III. In Ash from II.	IV. Total.	V. Direct combustion in oxygen.	VI. In Ash from V.	VII. Total.	VIII. Total by Eschka's method.	IX. Iron.
0·155	0·488	0·020	*0·663*	0·721	0·044	*0·765*	*0·733*	0·32
0·156	0·478	0·017	*0·651*	0·679	0·032	*0·711*		

Sulphur Determinations in Coke *E.*

0·119	0·532	0·012	*0·663*	0·637	0·021	*0·658*	*0·665*	
0·125	0·533	0·013	*0·671*	0·669	0·017	*0·686*		

Coal F.

Proximate Analysis.

Volatile matters (including moisture), .	29·75
Fixed carbon, . . .	62·37
Ash, ...	7·88
	100·00
Ash in coke, ...	9·80

Sulphur Determinations in Coal *F.*

I. By Bromine Mixture.	II. In residue from I by combustion in oxygen.	III. In Ash from II.	IV. Total.	V. Direct combustion in oxygen.	VI. In Ash.	VII. Total.	VIII. Total by Eschka's method.	IX. Iron.
0·349	0·560	0·014	*0·923*	0·923	0·045	*0·968*	*0·949*	0·666
0·354	0·546	0·012	*0·912*	0·905	0·043	*0·948*		

Sulphur Determinations in Coke *F.*

0·296	0·619	0·012	*0·927*	0·907	0·017	*0·924*	*0·917*	
0·299	0·607	0·008	*0·914*	0·913	0·024	*0·937*		

Coal G.

Proximate Analysis.

Volatile matters (including moisture). .	38·01
Fixed carbon, . . .	56·27
Ash, ...	5·72
	100·00
Ash in coke, . . .	8·76

Sulphur Determinations in Coal *G*.

I. By Bromine Mixture.	II. In residue from I by combustion in oxygen.	III. In Ash from II.	IV. Total.	V. Direct combustion in oxygen.	VI. In Ash from V.	VII. Total.	VIII. Total by Eschka's method.	IX. Iron.
0·129	0·588	0·018	*0·735*	0·749	0·042	*0·791*	*0·759*	0·290
				0·727	0·045	*0·772*		

Sulphur Determinations in Coke *G*.

0·085	0·516	0·025	*0·626*	0·581	0·050	*0·631*	*0·597*
				0·605	0·016	*0·621*	*0·590*

I add an analysis of anthracite, illustrating this method of treatment.

Anthracite.

Analysis of Ash. (5·11 per cent.)

Silica, ...	50·06
Alumina and iron, . . .	44·22
Lime, ...	1·39
Magnesia, . . .	0·21
Sulphuric acid, . . .	2·05
	97·93

Sulphur Determinations in Anthracite.

I. By Bromine Mixture.	II. In residue from I by combustion in oxygen.	III. In Ash from II.	IV. Total.	V. Direct combustion in oxygen.	VI. In Ash from V.	VII. Total.	VIII. Total by fusion with sodium carbonate and nitrate.
0·08	0·485	0·024	*0·589*	0·512	0·042	*0·554*	*0·589*
				0·534	0·040	*0·574*	

No calcium sulphate was found in any of these coals. They were tested by boiling for some time the finely pulverized coal with water slightly acidulated with hydrochloric acid, in a flask from which the air was excluded by a current of carbon dioxide. The precaution of excluding the air is necessary, since pulverized iron pyrites boiled with water (or solution of sodium carbonate, as has been recommended for the determination of calcium sulphate) with access of air is readily oxidized, and the water reacts for sulphuric acid.

In the second series of analyses it will be seen that there is in each case an excess of total sulphur over what is necessary to form pyrites with the iron, and that there is not enough sulphur, as determined by bromine, to form pyrites with all the iron. This would seem to indicate that the sulphur is present in these coals, both as pyrites and as an organic constituent of the coal, and also that the iron is present, both in combination with sulphur and with silica or other inorganic constituents of the ash.

The foregoing determinations, while they are insufficient to throw much light on the effect of coking on the condition or the elimination of sulphur in coal, may not be without value in indicating a new line of investigation of coals and cokes.

In the coal *A*, which contains sulphur in considerable amount, both as metallic sulphide and as an inherent constituent of the coal, and which at the same time is low in volatile ingredients, it would seem as if the elimination of sulphur was limited to a portion of that existing as pyrites, and that the organic sulphur, if we may so call it, was not affected by the process of coking. This becomes apparent if the percentage of sulphur in the coke is calculated on the basis of the amount of coa required to make the coke.

In the other coals, low in pyrites and higher in volatile matters, there was an elimination of the organic sulphur to the extent of 20 to 45 per cent. It would be interesting to determine the effect of different methods of coking, and of the duration of the process on this elimination.

If we admit the presence of organic sulphur in coke, it is probable that no plan for its removal could be effective which would not involve the destruction of the coke itself. In the method of analysis given we are able to distinguish between the organic and inorganic combinations of sulphur in coke, and thus to determine the feasibility of its desulphurization.

It is interesting to note (more especially in coal *A*) that the ash of the coal which has been burned directly in oxygen contains much more sulphur than that from the same coal which has had its sulphur, in the form of pyrites, removed by bromine.

The analytical determinations in this investigation were made with great care by Mr. P. W. Shimer.

NATURAL FILTRATION AT BERLIN.

By Prof. Wm. Ripley Nichols.

Of recent years, every one in this section of the country, who is at all interested in water supply, has become more or less familiar with some of the disadvantages which are attached to surface-waters and especially to ponds (and lakes) and impounding reservoirs. The "pondy" taste and the brownish color acquired by water in streams which pass through marshy and peaty ground, the trouble caused by certain *algæ,* especially those which may be classed under the general head of *Nostocs,* the peculiar and unexplained tastes and odors with which some supplies are affected—these are well known, and, recently, from the researches of Professor Remsen,* it would seem that the fresh-water sponges may, by their growth and decay, create offence and impair the quality of an otherwise good water.

There are those who would have us believe that, on account of these difficulties, some of which may be overcome by artificial filtration, surface supplies should be abandoned and efforts made to procure a sufficient supply from the "ground-water" by the process of "natural filtration." By this method the water is taken by means of wells, "filter-basins" or galleries from a water-bearing porous stratum, generally in the immediate vicinity of a river or lake, and the water obtained is, as a rule, a mixture of the ground-water of the locality with more or less water derived from the neighboring stream or lake, the former usually predominating.†

* Report of the Joint Standing Committee on Water, on the Impurity of the Water Supply, with the report of Prof. Ira Remsen. Boston City Document 143, 1881 (Nov. 21).

† The various methods of utilizing the ground-water and a full discussion of the source of the water obtained may be found in the author's "Filtration of Potable Water," New York, Van Nostrand, 1879.

While in many localities a very good water can be thus obtained, it is apt to be somewhat limited in quantity and is usually harder than the surface water of the region. Every form of water supply has, however, its peculiar difficulties, and the ground water is not free from them. It is proposed in the present article to give an account of a serious difficulty which has occurred in connection with such a supply in Berlin, Prussia.*

Nature of the Trouble.—Since September, 1877, a portion of the Berlin water supply has been taken from the neighborhood of the "Tegeler See" by means of a series or line of 23 wells running parallel with the shore of the lake. The wells are from 50 to 100 metres distant from each other and fourteen of them are 4·5 metres in diameter, while the remaining nine have a diameter of 4 metres. The water of the several wells is pumped at first into a small reservoir with a capacity of 2215 cubic metres; the wells are covered and the reservoir is vaulted over and is surrounded by and covered with earth. Thence the water is forced to the Charlottenburg reservoir, between 6 and 7 kilometres distant; this is likewise covered and has a capacity of 12,000 cubic metres. Connected with this reservoir is a "well" or "suction chamber," from which the pumps take the water for the city supply, the pressure being regulated by a stand-pipe or, rather, by two connecting stand-pipes each 1·2 metres in diameter and about 50 metres high.

Shortly after the introduction of the water, complaints arose as to its quality, and investigation proved the difficulty to be two-fold. It is frequently noticed that water—and especially water from a driven

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* The sources of information are the following reports, besides various articles in the *Journal für Gasbeleuchtung und Wasserversorgung*.

Bischoff, Dr. Carl. Bericht über die chemischen und mikroscopischen Untersuchungen der Wässer der Tegeler Anlage, u. s. w. 8vo, pp. 71. 4 plates and 13 tables. Berlin, 1879.

Brefeld, Prof. Dr. O. und Zopf, Dr. W. Bericht über die Untersuchungen des Tegeler Wassers. (March 20, 1879.) 8vo, pp. 50. Berlin, 1879.

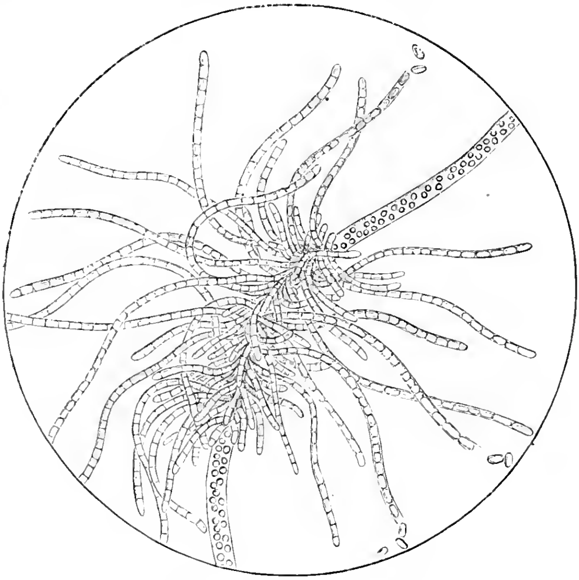
Zopf, Dr. W. Entwickelungsgeschichtliche Untersuchung über *Crenothrix polyspora*, die Ursache der Berliner Wassercalamität. 8vo, pp. 21, with 3 plates. Berlin, 1879.

Bischoff, Dr. Carl. Bericht über Untersuchungen filtrirten Brunnen und Seewassers der Tegeler Station, u. s. w. (December, 1880.) 8vo, pp. 97. Berlin, 1881.

Finkener, Prof. Bericht über die Untersuchung des Tegeler Wassers. (Jan. 6, 1881.) 8vo, pp. 18. Berlin, 1881.

Gill, Henry. Bericht über die Untersuchung des Tegeler Wassers. (Jan. 20, 1881.) 8vo, pp. 25, with plate and diagrams. Berlin, 1881.

well—although apparently clear when first drawn, becomes turbid on standing and deposits an ochreous sediment which consists mainly of amorphous hydrated oxide of iron. This is generally due to the presence in solution of the protocarbonate or to some organic proto-salt of iron, which—on exposure to the air—becomes oxidized and changed to an insoluble hydrated sesquioxide. This was one of the difficulties with the Tegel ground water; but the microscope showed that the ochreous sediment which settled from samples of the water and which accumulated in the reservoirs and in the pipes, especially in "dead ends," was by no means made up wholly of amorphous mineral matter, but consisted very largely of *algæ*, dead and alive.



Crenothrix Kühniana. 450:1.

Most noticeable among the *algæ* was the *Crenothrix Kühniana* (*Crenothrix polyspora, Cohn*). This plant was first discovered by Kühn in 1852, in the drains of a cultivated field in Silesia, but has since been found in wells in various parts of Germany and is probably very widely distributed. It has been called also *Leptothrix Kühniana* and *Hypheothrix Kühniana*, and its development was studied by Cohn and later, in connection with the Berlin trouble, by Zopf. In Berlin, it was found in the wells, in the reservoirs and in the service pipes in various stages of development and decay. The spores are minute

spherical or oblong bodies from one one-thousandth to six one-thousandths of a millimetre in diameter. From these spores, and by other means of development, the plants grow into comparatively long threads, each of which on examination is seen to be made up of a number of individual cells, end to end, inclosed eventually in a gelatinous sheath. The general appearance of a mass of these threads is shown in the figure, and the masses are sometimes a centimetre or more in diameter.*

The threads are at first, like the spores, transparent and colorless, but by the absorption of iron in some form or other they become colored from olive-green to a dark brown. They eventually, in many cases, become incrusted with the hydrate of iron to such an extent that their structure becomes invisible, but it may be made evident by dissolving away the hydrate of iron with very dilute chlorhydric acid. Under favorable circumstances, the plants may develop with great rapidity, and Professor Kühn speaks of their having frequently stopped up agricultural drain-pipes. Also, the pipes in which water is taken from a well, 10 metres deep, in the neighborhood of the Plötzensee, near Berlin, have in summer been choked and nearly filled up by the multiplication of the same organisms. In the reservoirs and in the "dead ends" of the service pipes they seemed to accumulate by growth as well as by deposition. While the plants develop more rapidly in the warm season, they are found at all times of the year in all stages of development.

Source of the Plants.—It having been found that the plants occurred in the wells themselves, it was thought by some that their presence was due to the imperfect exclusion of water from near the surface, and others thought that they had their source in the neighboring lake and were drawn through the intervening sand and gravel. With reference to the first point, Professor Finkener showed that there was no fault in the construction of the wells, but that, while the water from the upper layers became turbid on standing, this property was much more marked in the water of deeper origin. With reference to the second point, repeated and careful observations by different observers failed to discover the plant in the waters of the lake itself. (Bischoff, p. 43; Brefeld and Zopf, p. 5.) In fact the previous observations of Cohn

* The figure, which is adapted from Zopf, represents one of the thread-masses which has arisen by the germination of a number of spores still contained within the sheath. This is one of the methods according to which the plant develops.

and others would lead to the idea that the plant developed only in the dark, and Dr. Bischoff says: "On account of the entire absence of chlorophyll in the threads of the *Crenothrix* it seems to me justifiable to conclude that these organisms can exist only in the dark."* It seemed, then, that either the spores of the plant must in some way reach the wells from the outside and there develop, or else the plant must have its habitat in the ground itself. Accordingly, six driven wells were sunk to continually increasing depths in various localities in the neighborhood of the line of wells and, although the *Crenothrix* was not found at all depths in all of these driven wells, yet it did occur in each well at some depth or other. As it was found in all its various stages of development, the inference that the plant lived and grew in the ground itself would seem to be justified. It should be said, however, that this conclusion was not universally accepted, and Thiem, in a recent article† on ground-water supplies, speaks of it as an unsettled question. The reports of the observers seem perfectly clear, and in an examination which was made of the water from a number of wells in different parts of Berlin, the same plant was found in many cases, in one instance at a depth of more than 24 metres from the surface.

Remedial Measures.—At first, attempts were made to overcome the difficulty by diminishing the supply pumped, *i. e.*, by causing the water to pass less rapidly through the ground, and by frequent cleansing of the reservoirs; but these measures proved simply palliative, and it seemed that artificial filtration would be necessary. Various experiments were made in this direction, the most satisfactory being conducted in a filter constructed of masonry, vaulted over and covered with earth—resembling, in fact, the filters used on the large scale except in size. The area of the experimental filter-bed was nine square metres. It was found that, if the water was taken from the wells directly on to the filter, the filtered water—although at first clear—soon became turbid and deposited an ochreous sediment containing the *Crenothrix*. It was further found possible, by exposing the well

* Dr. Zopf found the *Crenothrix* in samples of the unfiltered and of the filtered water of the River Spree, but the Director of the Water Works, Henry Gill, says that the arrangements of the works are such that water from a deep well may become mixed with the river water, and of the occurrence of the plant in this well there was no doubt.

† *Journal für Gasbeleuchtung und Wasserversorgung*, xxiv (1881), p. 791.

water to the air, so that all the iron was oxidized and deposited before filtration, to obtain a filtered water which remained clear and in which the *Crenothrix* could not be found. It does not appear that experiments were made of exposing this filtered water to contact with iron as it would be if introduced into the service, so that it is not absolutely certain whether in the latter case the water was actually freed from spores or whether, spores being present, they failed to develop owing to the lack of the necessary conditions. Iron seems to be essential to the existence of the *Crenothrix,* and the threads, even when apparently colorless, are turned blue by ferrocyanide of potassium, thus showing the presence of iron. Of course the filter-sand was very much fouled and, on account of the difficulty of washing the sand thoroughly and the risk that the spores of the plant would eventually find their way into the lower part of the filters and thence into the service, it was thought best by those in charge of the works to abandon the wells altogether and to make use of water taken directly from the lake and filtered in the usual manner. It may be remarked, in this connection, that the *Crenothrix* has great vitality; thus, Dr. Zopf exposed a quantity in water out-of-doors from the first of January to the middle of February. The water was, of course, frozen and during the time the temperature fell as low as to —8°R. (11°F.), but after being thawed out the plants had, in a few weeks, contrary to all anticipation, revived again or new ones had grown from the spores.

Trouble in other Places.—The same trouble occurred in Halle, and it is stated that it was overcome by sinking other wells in a different locality. In the second locality the water was much harder and free from the *Crenothrix;* in fact, when it was mixed with water from the previous source it brought about the extermination of the plant; hence it has been inferred that the presence of a considerable amount of carbonate of lime is fatal to the plant.

Trouble in this Country.—No case precisely similar to that described above has come to my notice in this country, but I had occasion some time ago to examine somewhat cursorily a case having some points of resemblance. A town in the eastern part of Massachusetts was troubled with its water supply, the trouble consisting in an ochreous substance which was in the pipes and was discharged at the faucets, giving the water when first drawn a reddish appearance. When the water was allowed to stand it did not become turbid but the red particles contained in the water settled at the bottom in light flocculent

masses which the microscope showed to be made up largely of vegetable organisms. The source of supply was a small artificial and quite shallow pond, but at the time of my visit the water was not taken directly from the pond, but by means of an imperfectly constructed "filter-gallery" in the bed of the pond. As the water entered the main it was somewhat turbid, and if it was allowed to stand it deposited a rusty sediment, showing that the trouble did not originate in the pipes although it seemed to increase there.

Along the line of the main pipe, between the pond and the centre of the town, almost every hydrant when opened poured forth at first a stream of reddish-brown muddy liquid. After a time the water ran clear and I was informed that, although the pipes were flushed in this way by frequent openings of the hydrants, the same large amount of muddy water was as a rule always obtained. I did not in this case have the time to give to the study of the particular plant or plants which caused the trouble nor did I have the means to employ expert botanical assistance, so that I cannot say whether the *Crenothrix* was present or not. There was something of the same general character and that was all that it was necessary to know for the immediate purpose. Many of the *algæ* seem to attract hydrate of iron from water from which it is depositing;* even some of the larger *algæ*, the so-called *confervæ*, are often found incrusted with iron hydrate. This may be mainly a mechanical attraction, for even dead twigs and other solid objects become thus coated, but where the carbonate of iron is kept in solution by carbonic acid (as bicarbonate), the absorption of carbonic acid by the plant plays a part in the process by setting free the carbonate of iron which, however, is oxidized as fast as set free. It was noticed in Berlin that carbonate of lime was set free in a similar manner from the water in which it was kept dissolved by carbonic acid (as bicarbonate).

In closing, it may be worth while to say that the mere fact of the occurrence of a rusty sediment in a water does not prove the presence of the *Crenothrix* or of a similar *alga*. Thus, some time ago there was complaint of dirty water in a New England city which has an excellent water supply (surface water). The water came as a reddish mixture from the faucets and a rusty sediment settled in the vessels in

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* Such, for instance, is the *Lyngbya ochracea* (formerly called *Leptothrix ochracea*) which is a rusty-colored, slimy plant found on the submerged iron of almost all water works. See *Farlow*, 1*st Annual Report Mass. State Board of Health, etc. Supp. p.* 151.

which the water was allowed to stand; the water was unfit for domestic use except after filtration. The trouble was found to be confined to the lowest section of the service, where the use of the water was not very great, and it was due, without doubt, to the settling into this lowest section of dirt and iron rust from the pipes, and the accumulation readily took place owing to the slowness of the current. A fire occurring in the region flushed the pipes so thoroughly that for a time the trouble was removed. Of course, frequent flushing of the pipes was the only remedy in a case like this.

SILK CULTURE IN THE UNITED STATES.

By Lorin Blodget.

A paper read at the Stated Meeting of the Franklin Institute, Wednesday, Feb. 15, 1882.

I appear before you at the request of your much respected Secretary, to state very briefly some points in the progress of the silk industry.

I have very short time given me to represent before your Association some of the more important features of this general question, and I will first ask your attention to the peculiarities of the silk fibre, as illustrated by microscopical examination, for the reason that these show, as I think, the most encouraging conditions as to quality, if not the superiority of the American silk fibre over that in general use.

The silk industry which I take to be the true significance of the words silk culture, as expressed on your invitation, is the third great industry of the textile class in this country, amounting to nearly $50,000,000 in value yearly, as now represented by actual manufactures, as compared with $250,000,000 in value of cotton manufactures, and $300,000,000 in value of manufactures of woolen and woolen mixed goods. The importation of silk goods is about $35,000,000 in value, making eighty-five millions of dollars as the value of silk goods entering into consumption in this country for a year.

This industry in silk manufactures has grown very rapidly from very moderate proportions ten or fifteen years ago to what I now state, or to forty-five millions at least, if we take the figures of the census of 1880.

In cotton and in wool we produce the raw materials of these vast

industries here, as a matter of course, but in silk we stand in the anomalous condition of producing as yet nothing of consequence in this country. Great as the country is, and great as the demand is for raw silk, we permit our superior natural advantages to remain unimproved, and we import about four million pounds of raw silk for manufacture here, nearly three millions of pounds reeled, and one million of pounds of spun and waste silk. Such is the unnatural and unnecessary condition of dependence of this industry on raw silk brought from the most remote sources, chiefly from Japan and China.

This great industry has more phases than I can represent, but one of the most important and interesting to the members of this Institute is the machinery required for silk manufacture. In this case, as in many similar cases, American genius is attaining results far in advance of those in use in the old world. We have in operation in the city of Philadelphia several new machines and combinations of machinery far superior in efficiency to those employed in Europe in similar branches of silk manufacture. One of these I have recently examined and illustrated, the power chenille cutter, invented in Philadelphia, and adapted to a wide range of fabrics.

Another important class of machinery is that of compound looms. There are in this city several hundred, each doing the work of ten, twelve or sixteen hand loom weavers in Europe, and but one person, perhaps, being required to two of these, each weaving from eight to sixteen silk webs of different widths, according to the width of the fringe or the width of the ribbon, or of narrow goods in any form. The same economy is effected in handkerchiefs, and it is to this superiority of design generally, in the construction and application of machinery to the smaller classes of silk goods, that the rapid development of this class of manufactures is due.

I can show you in one establishment at Fairmount one hundred of these compound looms, weaving and automatically cutting silk chenille and fringe of the most delicate kind, the processes being conducted in an automatic manner, and representing the economy we have attained, and the superiority of adaptation through which we have become successful in the manufacture of these goods.

Now as these processes are conducted almost entirely upon raw silk imported from foreign countries—Japan and China—it is very important to know whether the same principles of economy—the same adaptations of invention and skill, are or are not applicable to the

preliminary processes of growing silk, of reeling and of fitting silk from the cocoon to pass to the hand of the weaver.

You have before you, and I hope your Secretary will explain it, a reel almost as much improved in the matter of efficiency over the hand reels used in Italy as the machinery I have described to you—the chenille cutter and the power loom—are in the final manufacture of silk. You have the processes for growing silk and for reeling silk, to be examined and adapted, and if they are capable of the economies we suggest it becomes almost entirely unnecessary to ask whether we can grow silk in this country. That question is asked many times, and has been answered in the negative many times, yet I think, after all, it is a very absurd question. We may, with the same propriety, ask whether a farmer in this country can grow cotton at eight cents per pound. That is a question analagous to that of asking whether silk can be grown at $1.00 per pound for cocoons or $6.00 a pound for reeled silk.

It is not a question whether capital could stand the burden of a distinct and separate investment for this purpose, but whether the farmer could add the culture of silk to his other engagements and labor, and could live in part upon this as one of his resources. It is a question whether he could do so in cotton or in wool—for in fact there is no description of farming in the United States that would pay if conducted by the isolation of any one of these products. You could not, separately, grow 500 pounds of wool annually and make it pay, or 50 bales of cotton—and of course you could not grow 400 pounds of silk cocoons in this way and make it pay. It is by the combination of these or other products that farming is made profitable in this country, and in all other countries the same economy alone causes the production of silk to be made remunerative. If they can grow it in Italy, we can grow it here; and for the same reasons which apply in proving that if they can grow cotton in India, we can grow it in the Southern States. To-day we produce nearly $300,000,000 in value annually of raw cotton in the United States, often without profit to the careless planter, but with great profit to the country. I regard the conditions of growing silk as presenting circumstances much more favorable on the whole in this country, for reasons very easily stated. Silk raising where the trees are already grown does not require any considerable investment of capital, nothing for the purchase of land, or of the purchase of fer-

tilizers for the soil, or for the mules indispensable on the Southern plantation. It can be done by any one member of any family or by as many more as may choose to engage in it. It is not field work, and therefor not labor to be paid for in cash.

It is very easy to prepare for it on any of the farms of the interior or near the cities. It is not wholly new to urge the production of silk here; it has been recommended many times and by high authority. I have in my hand the proof that the Philosophical Society of this city started a fund for the growing of silk at an early day and to which the most eminent citizens of this city contributed in 1770, and the statement before me alleges that this society now holds in trust a fund contributed for that purpose, which I hope may be made available. Before referring to the recent movement by which the silk manufacture has been most effectively encouraged, I wish to show you some samples of raw silk made here by our own people—the Women's Silk Culture Association of Philadelphia.

A great deal of very inferior silk from India and other remote countries is now used—not so much here as in Europe. Here are specimens of it. The product of an inferior class of moths, which may be generally distinguished as the *Attacus*, whereas the true silk moths, the *Bombyx*, differ widely. (A moth with a black cocoon exhibited.) I have examined many of these cocoons and their fibres under the microscope. I find that the black cocoon yields a flat, coarse, apparently hollow fibre, inferior in every respect to the true silk. I can take many descriptions of silk goods sold in this country to-day which contain this inferior fibre. From a few cocoons obtained some months ago I had reeled immediately the specimens now shown and which have not been taken from the case since the reeling was done, and this silk presents a striking contrast. I have here an imported specimen of raw silk that has not been taken from the envelope, sent as the best grown in France, yet it is certainly not better than the sample reeled here, and most persons would pronounce it inferior in strength and elasticity of fibre.

Your Secretary gives me some silk reeled upon the new reel, constructed under his direction for the Women's Silk Culture Association, which I think you will find presents some characteristics of superiority as compared with any of the others, and which shows that the silk grown here from ordinary cocoons in the city of Philadelphia is at least equal to the best. Of the samples I have before me, derived

from various sources, those reeled here in Philadelphia are the best by all the tests that I can apply.

I should not have given so much attention to this point of distinction, although it is a very important one, except that in the *Paterson Guardian* of February 10th there appears an article especially discrediting American silk. In this article several specious and apparently plausible reasons are given why silk cannot be economically grown here, but its main point is in the assertion that American silk is inferior, and not fit for the best woven fabrics. It is also asserted that the quantity grown here is scarcely sufficient even for the single dress now in progress of manufacture to be presented by the Association to Mrs. Garfield. I will not repeat the language of this most unjust and untruthful criticism, but I will answer it in part by saying that there were five thousand pounds of cocoons grown in the last year, now waiting for anybody that will set up a reel. The country was not scoured to obtain the quantity now used; it has been obtained without difficulty, and it is not true that it is of an inferior quality. All the silk produced by the Ladies' Association is equal, and much of it superior, to that imported as the best Italian. I have no doubt of its quality, and I have examined it critically on many occasions.

I have here microscopic tests of perhaps ten or twelve different silk fibres and fabrics, and in all cases this form of examination shows precisely what character of fibre is employed in the manufacture. In examining the thread of which a certain class of fringes is made—it is found to be inferior—it is waste silk and quite worthless for wear. All these fabrics disclose their qualities under the microscope as distinctly as if the fibres were a sixth of an inch in diameter. I speak of this because it is often said that the American raw silk product is itself as far behind in quality, and therefore as far inferior in capacity for fine manufactures, as the state of the manufacturing industry was a few years since said to be behind that of France. It was then insisted that it would be impossible ever to produce superior goods. I will guarantee that where the same number of fibres are reeled from the cocoon in the raw silk reeled here, taking an average of the specimens, that the fabric ultimately produced will weigh heavier in dress goods, or in handkerchiefs, than if made of the same number of cocoon fibres sent here as Italian. If this is true, it is sufficient to show that the silk producing industry is not likely to fail here.

As to the manner in which the change shall be brought about, and

the introduction of this industry of raw silk shall be secured, I hope you will allow me to call to your attention the work of the organization called the "Women's Silk Culture Association of the United States" which has, since April, 1880, conducted a correspondence with several hundred persons in different parts of the United States, and in the way of suggestion, of encouragement, of instruction, and by all the methods available to them, have made the growth of silk a subject of national pride and of public economy. More than all, they have made it a matter of especial benevolence to many who suffer for want of employment, and for want of practicable methods by which their time can be turned into money. I think these ladies deserve the highest measure of honor that can be given them, whether they succeed in their attempt as a business enterprise or not. This is not attempted in the ordinary sense except that they hope to make the account of receipts and expenses balance at the end of the year, and this they have done. The most important question is, whether their efforts, impartial as they are, public-spirited in the best sense, and prompted by the highest benevolence, as well as pursued with the most persistent energy, are likely to attain their object.

In my judgment their prospects now offer great encouragement to all who have been associated with their undertaking. No taint or private profit or speculation attaches to it, nor has it any real obstruction likely to defeat its objects. They are now closing their second, and entering upon their third year of active labor, and the demand all over the country is very great for the information and the instruction which they give to all applicants.

In urging the public to give this work their attention I have no other purpose than to discharge the economic duties which I have, to a certain extent, assumed for a great many years. I earnestly insist that an industry like this ought to receive the encouragement of the people, the encouragement of the Legislatures of the States, and the encouragement of Congress. There is nothing in the way of developing an industry that will at once bring to the Central and Southern States a great accession to the resources of the people, and a help rather than a hindrance to the cotton industries of those States.

The Secretary at the close of Mr. Blodget's remarks gave, by request, the following explanation of the improved iron frame silk reel lately constructed for the Women's Silk Culture Association, viz.: A year or so ago the association, after considerable trouble, succeeded

in getting a pattern of the reels which were said to be in use in France and Italy, a clumsy affair, all of wood, which stood upon four legs, like a table. After it had been in use a little while it warped and became so troublesome to use that it occurred to some of the members of the Advisory Board to have a mechanical reel constructed of metal, which would work more accurately, and represent in an improved form the best ideas we had upon the subject. This was finally decided upon, and after some consultation the speaker was requested to secure the services of an expert machinist to construct such a reel. Mr. Hugo Bilgram, a member of the Institute, was requested to undertake the work, and the result of his intelligent comprehension of the subject you see in the admirable, light, easy and rapid running reel, which I take pleasure in showing you this evening, and which I believe has been found eminently satisfactory. It is constructed entirely of metal; it is very light and compact, and devised in such a manner that it can be closed together in a very compact form when not in use, or when it is to be removed from place to place. While there is no new mechanical feature in it, it represents generally the construction of the hand reels of France and Italy.

The silk is wound upon the reel, and the motion is communicated to the reel by hand. The driving wheel is grooved, and motion is transmitted to a smaller grooved pulley in the shaft of the reel, the proportions between driving and driven pulley being as 4 to 1. The traverse which effects the crossing of the strands on the reel is given by an open cam on the driving shaft. This engages with a bell-crank lever, connected with a brass sleeve upon a cross bar above, which slides back and forth with the motions of the lever arm. The guides through which the silk threads pass to be wound on the reel are attached to this sleeve, and they are thus given the required crossing.

The reel works with great accuracy, and without jar or lost motion, and it has proved to be most satisfactory as a first effort to construct such a machine in metal.

The skilled reeler employed by the association is enabled to reel more than double the quantity of silk upon this than upon the old wooden reel, a result highly gratifying to the association, and one that has a very important bearing on the question of the profitable reeling of silk by hand in the United States.

ACTION OF FREE MOLECULES ON RADIANT HEAT, AND ITS CONVERSION THEREBY INTO SOUND.

By J. Tyndall, F.R.S.

Abstract of the Bakerian Lecture for 1881.

The lecture opens with a brief reference to the researches of Leslie, Rumford, and Melloni. The labors of Tyndall and Magnus, as far as they bear upon the present subject, are then succinctly sketched, their points of difference being signalized and briefly discussed. This preliminary sketch is wound up by a reference to a recently published paper by Lecher and Pertner, who, while supporting the lecturer in the matter of gases, dissent from him in the matter of vapors. These investigators are especially emphatic in affirming the neutrality of aqueous vapor to radiant heat. Following Magnus, they refer Tyndall's results to what Magnus calls "vapor-hesion," that is to say, to the condensation of the vapors on the surfaces of the plates of rock-salt used to close the experimental tube, and on the interior surface of the tube itself.

In November, 1880, the lecturer's investigations in this field were resumed. Former experiments were repeated and verified with divers sources of heat, and with various experimental tubes—some polished within, and others coated inside with lampblack. The results obtained with the one class of tubes are substantially the same as those obtained with the other.

But even a coating of lampblack may be supposed to reflect a certain amount of heat, hence the desirability of an arrangement whereby internal reflection should be entirely abolished. This was accomplished in the following manner: A spiral of platinum wire, rendered incandescent by a voltaic current of measured strength, was chosen as a source of heat. An experimental tube 38 inches long and 6 inches in diameter had two circular apertures at its ends, closed by transparent plates of rock-salt, 3 inches in diameter. The tube was furnished with three cocks—one connected with a large Bianchi's air-pump; another with a purifying apparatus; while through the third vapors and gases could be admitted. Prior to entering the tube, the calorific rays were sent through a very perfect rock-salt

lens, by means of which an image of the spiral was formed on the most distant plate of rock-salt. To obtain the image with clearness, the spiral was first rendered highly luminous, and afterwards reduced, by the introduction of resistance, to the required temperature. In this way a calorific beam was sent along the axis of the experimental tube without at all impinging upon its interior surface. No reflection came into play; no absorption by hypothetical liquid films, coating the internal surface, could occur; and yet experiments made with this arrangement entirely confirmed the preceding ones, wherein by far the greater quantity of heat which reached the pile had undergone reflection.

When the source of heat was changed to a carefully worked cylinder of lime, a portion of which was rendered incandescent by an ignited stream of coal-gas and oxygen, the results were confirmatory of those obtained with the spiral. The order of absorption in both cases was the same, the only difference being that the fractional part of the total radiation absorbed in the case of the lime-light was less than that absorbed in the case of the spiral.

To condense a radiation from the lime-light, concave mirrors were sometimes employed, and sometimes rock-salt lenses. The results in both cases were identical.

An experimental tube of the dimensions here given was employed by the lecturer to check his results more than ten years ago. Its interior surface was rough and tarnished, and when warmed dynamically by the entrance of a gas its power as a radiator enabled it to disturb, to some slight extent, the purity of the results. To obviate this, the experimental tube recently employed was provided with an internal silver surface, deposited electrolytically and highly polished. By this arrangement the radiation of the tube itself, as well as its absorption, was rendered quite insensible.

The rock-salt plates used to close the experimental tube, and on which liquid films are alleged to be deposited, remain to be examined. In this case also an *experimentum crucis* is possible. If the observed absorptions be due to such liquid films, then the separation of the salts more widely from each other, the space between them being copiously supplied with vapor, ought to produce no effect; but if the absorption, as alleged by the lecturer, be the act of the vapor molecules, then the deepening of the absorbing stratum ought to produce an augmented effect. For many gases and some vapors this

problem was solved as far back as 1863. By means of an apparatus then described, polished plates of rock-salt could be brought into contact with each other, and then gradually separated, until the gaseous stratum between them was some inches in depth. With sulphuric ether vapor the distance between the plates being $\frac{1}{20}$ of on inch, an absorption of 2 per cent. was observed. With a thinner stratum, or a weaker vapor, even this small absorption vanished; while in passing from $\frac{1}{20}$ of an inch to 2 inches the absorption rose from 2 per cent. to 35 per cent. of the total radiation. Such experiments, recently verified, entirely dispose of the hypothesis that liquid films were the cause of the observed absorption.

The "vapor-hesion" hypthesis involves the assumption that liquids exert on radiant heat an absorbent power which is denied to their vapors. It assumes, in other words, that the seat of absorption is the molecule considered as a whole, and not the constituent atoms of the molecule. For were the absorption intra-molecular, the passage from the liquid to the vaporous condition, which leaves the molecules intact, could not abolish the absorption. So far back as 1864 the lecturer had proved that when vapors, in quantities proportional to the densities of their liquids, were examined in the experimental tube, the order of their absorptions was precisely that of the liquids from which they were derived. This result has been recently tested and verified in the most ample manner by means of the apparatus in which internal reflection never comes into play. It furnishes, therefore, the strongest presumptive evidence that the seat of absorption in liquids and in vapors is the same.

As a problem of molecular physics it was, however, in the highest degree desirable to compare together *equal* quantities, instead of proportional quantities, of liquids and vapors. Highly volatile liquids alone lend themselves to this experiment, for only from such liquids can vapors be obtained sufficient, when caused to assume the liquid form, to produce layers of practicable thickness. Two cases, however, have been very fully worked out, the substances employed being the hydride of amyl and sulphuric ether. Careful and exact experiments, many times repeated, lead to the result that when the number of molecules traversed by the calorific rays in the vapor is the same as that traversed in the liquid, the absorptions are identical. In the silvered experimental tube, which, as stated, is 38 inches long, hydride of amyl vapor, at a mercury pressure of 6·6 inches, is equivalent to a

liquid layer 1 millim. in thickness, while a vapor column of sulphuric ether, of the same length, and 7·2 inches pressure, would also produce a liquid layer 1 millim. thick. The experiment has been made with the utmost care, both with the lime-light and the incandescent platinum, with the result that it is impossible to say that there is any difference between the vapor absorption and the liquid absorption. In the face of such facts the "vapor-hesion" hypothesis, as an explanation of the results published by the lecturer, cannot be sustained.

On the 29th November, 1880, he had the pleasure of witnessing, in the laboratory of the Royal Institution, the experiments of Mr. Graham Bell, wherein a concentrated luminous beam, rendered intermittent by a rotating perforated disk, was caused to impinge upon various solid substances, and to produce musical sounds. Mr. Bell's previous experiments upon selenium naturally led him to conclude that the effect was produced by the luminous rays of the spectrum. The contemplation of these experiments produced in the lecturer the conviction that the results were due to the intermittent absorption of radiant heat. He was experimenting on vapors at this time. Substituting in idea gaseous for solid matter, he clearly pictured the sudden expansion of an absorbent gas or vapor at every stroke of the calorific beam, and its contraction when the beam was intercepted. Pulses far stronger than those obtainable from solid matter would probably be thus produced, which, when rapid enough, would generate musical sounds. The intensity of the sound would, of course, be determined by the absorptive power of the gas or vapor.

This idea was tested on the spot. Placing sulphuric ether in a test-tube, and connecting the tube with the ear, the intermittent beam was caused to fall upon the vapor above the liquid. A feeble musical sound was distinctly heard. Formic ether was tried in the same way, and with the same result. Bisulphide of carbon was then tried, but the vapor of this liquid proved incompetent to generate a musical sound. These results, which were in perfect accordance with those previously enunciated by the lecturer, were first made public during a discussion at the Society of Telegraph Engineers on the 8th of December, 1880. (*Journal of Telegraph Engineers*, vol. 9, page 382.)

It was obvious, however, that the arrangement of Mr. Bell—a truly beautiful one—was not suited to bring out the maximum effect. He had employed a series of lenses to concentrate his beam, and these, however pure, would, in the case of transparent gases, absorb a large

portion of the rays most influential in producing the sound. The lecturer, therefore, resorted to lenses of rock-salt and to concave mirrors silvered in front. He employed various sources of heat, including that of the electric lamp. The lime-light he found very convenient. With the lime-light and concave mirror, sounds of surprising intensity were produced by all the highly absorbent gases and vapors. Among gases chloride of methyl was loudest. Conveyed directly to the ear by a tube of india-rubber, the sound of this gas seemed as loud as the peal of an organ. Abandoning the ear-tube, and choosing a suitable recipient for the gas, the sounds were heard at a distance of 20 feet from their origin. As regards intensity, the order of the sounds, in gases, corresponds exactly with the order of their absorptions of radiant heat.

Among vapors sulphuric ether stands highest, this result being in part due to the great volatility of the liquid. But the intensity of the sound is by no means wholly dependent on volatility. The specific action of the molecules on radiant heat is as clearly shown in these experiments as in those previously conducted with the experimental tube and thermopile. Upwards of eighty vapors have been tested in regard to their sound-producing power.

With regard to aqueous vapor, whose action upon radiant heat even the latest publications on this subject describe as *nil*, it was especially interesting to be able to question the vapor itself as to its absorbent power, and to receive from it an answer which did not admit of doubt. A number of bulbs about an inch in diameter were placed under the receiver of an air-pump, with a vessel containing sulphuric acid beside them. When thoroughly dry they were exposed to an intermittent beam. The well-dried air within the bulbs proved silent, while the slightest admixture of humid air sufficed to endow it with sounding power. Placing a little water in a thin glass bulb, and heating it nearly to its boiling point, the sounds produced by the developed vapor are exceedingly loud. The bulbs employed in these experiments are usually about a cubic inch in volume. They may, however, be reduced to one-fiftieth or even one one-hundreth of a cubic inch. When a minute drop of water is vaporized within such little bulbs, on their exposure to the intermittent beam loud musical sounds are produced.

It is to be borne in mind that the heat employed in these experiments, coming as it did from a highly luminous source, was absorbed

in a far smaller degree than would be the heat from bodies under the temperature of incandescence.

To render the correlation of sound-producing power and adiathermancy complete, all the gases and vapors which had been exposed to the intermittent beam were examined as to the augmentation of their elastic force through the absorption of radiant heat. A glass cylinder, 4 inches long and 3 inches in diameter, had its ends closed with transparent plates of rock-salt. Connected with this cylinder was a narrow U-tube, containing a colored liquid which stood at the same level in the two arms of the U. The cylinder could be exhausted at pleasure or filled with a gas or vapor. When filled, the sudden removal of a double silvered screen permitted the beam from the lime-light to pass through it, the augmentation of elastic force being immediately declared by the depression of the liquid in one of the arms of the U-tube and its elevation in the other. The difference of level in the two arms gave, in terms of water-pressure, a measure of the heat absorbed. With the stronger vapors it would be easy with this instrument to produce an augmentation of elastic force corresponding to a water-pressure of a thousand millimetres. As might be expected, the intensity of the sounds corresponded with the energy of the absorption, varying from "exceedingly strong," "very strong," "strong," "moderate," "weak," to "inaudible." In this connection reference was made to the interesting experiments of Professor Röntgen, an independent and successful worker in this field.

In conclusion, the lecture draws attention to the bearing of its results upon the phenomena of meteorology. The views of Magnus regarding the part played by mist or haze are referred to and attention is directed to various observations by Wells which are in opposition to these views. The observations of Wilson, Six, Leslie, Denham, Hooker, Livingstone, Mitchell, Strachey, and others are referred to and connected with the action of aqueous vapor upon solar and terrestrial radiation. Many years ago the lecturer sought to imitate the action of aqueous vapor on the solar rays by sending a beam from the electric light through a layer of water, and afterwards examining its spectrum. The curve representing the distribution of heat resembled that obtained from the spectrum of the sun, the invisible calorific radiation being reduced by the water from nearly eight times to about twice the visible. Could we get above the screen

of atmospheric vapor, a large amount of the ultra-red rays would assuredly be restored to the solar spectrum. This conclusion has been recently established on the grandest scale by Professor Langley, who on the 10th of September wrote to the lecturer from an elevation of 12,000 feet on Mount Whitney, "where the air is perhaps drier than at any other equal altitude ever used for scientific investigation." An extract from Professor Langley's letter will fitly close this summary: "You may," he says, "be interested in knowing that the result indicates a great difference in the *distribution* of the solar energy here from that to which we are accustomed in regions of ordinary humidity, and that while the evidence of the effect of water vapor on the more refrangible rays is feeble, there is, on the other hand, a systematic effect, due to its absence, which shows, by contrast, its power on the red and ultra-red in a striking light. These experiments also indicate an enormous extension of the ultra-red rays beyond the point to which they had been followed below, and being made on a scale different from that of the laboratory—on one indeed as grand as nature can furnish—and by means wholly independent of those usually applied to the research, must, I think, when published, put an end to any doubt as to the accuracy of the statements so long since made by you, as to the absorbent power of water-vapor over the greater part of the spectrum, and as to its predominant importance in modifying to us the solar energy."—*Proceedings Royal Society.*

Use of Petroleum as Fuel in Russia.—Upon the Balachanskoi Railway the locomotives are heated with crude naphtha, which is introduced into the tender as it comes from the wells, and there have been no accidents resulting from its use. All the ships upon the Caspian Sea are heated exclusively with the liquid combustible, the cost being only half as great as that of coal. Experiments which have been made upon some of the railways show that a kilogramme of naphtha is equivalent to $8\frac{1}{2}$ kilogrammes of wood, although the theoretic heating power is only three times as great. The use of petroleum with injectors for introducing it into the furnaces is very convenient—the combustion can be regulated with the greatest ease; the furnaces last much longer on account of the absence of sulphur; there are no cinders, smoke or sparks, and the work of the stokers is greatly simplified.—*Soc. des Ingen. Civils.* C.

Security against Counterfeiting.—N. J. Heckmann adds five per cent. of cyanide of potash and sulphide of ammonium to the sizing water, and passes the sized paper through a thin solution of sulphate of magnesia or copper. If any attempt is made to remove writing from such paper by means of acids or alkalies the tint of the paper is immediately changed. If any erasures are attempted the coloring matter, which is only upon the surface, is removed.—*Dingl. Jour.* C.

Planets and Sun Spots.—Adolph Duponchel has presented a communication to the French Academy upon the agreement of the curve of sun spots with the actions resulting from the eccentricity of the principal planets. Faye has criticised the paper, and Duponchel has answered his criticisms by certain predictions, which he submits as tests of his theory. He thinks there will be an increase of the mean temperature in any given place during the twelve years to come over that of the twelve years which have just passed. Uranus and Neptune are about receding from their perihelia, and he anticipates an effervescence in the solar atmosphere, analogous to that which occurred between the years 1716 and 1725. He thinks this will be accompanied by an increasing frequency of spots, of which the maximum will occur, not in 1882 as is generally supposed, but between 1888 and 1892.—*La Nature.* C.

Observations in the Clouds.—The French society of aerial navigation has entrusted MM. Dutèt-Poitevin and du Hauvel with different balloon observations, among which was the study of the formation of clouds, taking into account the vapor tension in neighboring strata of air but of different temperature, and also the study of the release of the latent heat of vaporization at the moment of precipitation. The observations yielded the following results: 1. The clouds are formed in the zone of mixture of two layers of air saturated mith moisture. 2. The clouds originate in the warm layer and dissolve in the colder layer. 3. They move in the direction of the belt of air which has the highest temperature. 4. The winds which are observed at the surface of the ground, which are only effects of the reaction of the principal wind, may have a height of several hundred yards, and may have different directions in neighboring localities, while the upper current has a great regularity of direction and intensity.—*Comptes Rendus.* C.

Periodic Variations of Glaciers.—M. F. A. Forel, of Morges, presented to the first general meeting of the Swiss Society of Natural Science his investigations upon the periodic variations of glaciers. The present remarkable period of glacial retreat began about 1840 in some places, but the Unteraar glacier did not begin to diminish until about 1871. The period is now coming to an end and many of the glaciers are beginning to increase again. The differences of length are immediately traceable to periodic variations in the velocity of flow, which are due to corresponding variations in the thickness of the glacier. These are due partly to differences of snow-fall upon the summits, partly to variations in the summer heat; the latter cause has probably only secondary influence. The retreat which is just ending is attributable to a deficit of snow which dates back from 40 to 60 years and a series of warm summers for the past 20 years.—*Les Mondes.* C.

Influence of Dust upon Explosions.—M. L. Aguillon gives a summary of the principal facts which seem to have been established by Prof. Abel's experiments upon the influence of dust on mine explosions. One of the most sensitive of the Seaham powders contained the least proportion of carbon, and more than one-half of its material was incombustible. The special experiments which were suggested by this observation showed that powders which are entirely incombustible, and are not susceptible of any chemical change through the action of flame, become very dangerous when brought in contact with a mixture of air and fire-damp. This effect seems to be attributable, at least in part, to the fact that the particles, in passing through a flame, become incandescent so as to localize and increase the heat. One of the powders formed an explosive mixture in air containing only 2 per cent. of gas, and when a current of air was blowing with a velocity of only 5 decimetres (19·7 inches) per second, one and a half per cent. of gas was sufficient to make the mixture explosive. The coal dusts in mines not only develop and extend explosions, but through their rapid inflammability and their disposition to remain suspended in currents of air,. but they may also intervene as a means of propagating a flame rapidly as far as they extend, and rendering a proportion of fire-damp explosive which would not otherwise be dangerous.—*Ann. des Mines.* C.

Tunnel of the Arlberg.—The length of the tunnel is to be 10,270 metres (6·382 miles). The culminating point is to be 4205 metres (2·611 miles) from the eastern extremity, at an altitude of 1310 metres (1332·63 yards) above the Adriatic. The work was begun in June, 1880. Two perforators are used; at the eastern end the Ferroux machine, which was employed in the St. Gothard tunnel, acting by percussion and moved by compressed air; at the west end is the Brandt machine, which is moved by water under pressure, and drills by boring. It had given excellent results at Pfoffensprung, upon the Swiss side of the St. Gothard line, and the inventor guaranteed an advance of at least two metres per day, a guarantee which has been largely exceeded. The simultaneous employment of the two engines is especially interesting, since it will allow a comparison under identical conditions, and will have a great influence upon the choice of methods in the piercing of future tunnels. The ventilation will be made by a separate apparatus, distributing air under a low pressure, through tubes carried into the neighborhood of the workmen. The specifications provide for a minimum volume of 150 cubic metres per minute for each workman. At St. Gothard the supply rarely reached 100 cubic metres.—*Jour. de la Soc. Autrich.* C.

Curious Acoustic Phenomenon.—M. Reulaux reports a singular instance of the production of sound by natural causes. During a hunt upon the Röderbacherthal he passed through a valley, broad upon the eastern side, but narrowing rapidly towards the west, so as to form a kind of defile. The wind was blowing from the southwest, and the observer was marching upon the eastern declivity, when he seemed to hear repeated strokes of a fine deep-toned bell. There was no bell in the neighborhood, and other sounds which he heard soon proved that the phenomenon was meteorological. The sounds increased in intensity, and then diminished after having passed through a maximum. They resembled, at times, those of an organ, and at other times those of a harp or violin. At the entrance of the defile, from which the sounds seemed to come, there arose a strange agitation of the air, when the sounds became confused, and some of the notes suddenly ceased. M. Reulaux supposes that currents of air were forced through the gorges, and that the sound was due to a conflict between the exterior and interior air, which produced musical vibrations. There was a very marked difference of temperature between the upper and

lower portions of the valley, so that the upper cold current pressed upon the lower and warmer air, thus closing the gorge so as to make a kind of tube. There appeared to be no wind except in the lower part of the gorge.—*Les Mondes.* C.

New Treatment of Distillery Refuse.—The weak liquors which escape from the distilleries injure the water of streams and springs, and in some cases become a medium of infection for the whole neighborhood. MM. Gaillet and Huet add to the liquors perchloride of iron in suitable proportion, mixing the ingredients thoroughly. After the first reaction is completed milk of lime is stirred in, which precipitates the sesquioxide of iron, carrying with it almost all the organic matter. The remaining liquid is perfectly clear, colorless, harmless, not liable to fermentation and offering no inconvenience to the public health. The precipitate forms a manure, very rich in nitrogen and in phosphoric acid. The sale of the manure not only frees the refuse from being a burden upon the industry, but also makes it a source of profit.—*Les Mondes.* C.

Relation of Atmospheric Resistance to Temperature.—Hirn has presented a memoir to the Belgian Academy in which he gives the results of numerous experimental researches upon the relation which exists between the resistance of the air and its temperature. The hypothesis of Clausius, upon the constitution of gases, was supposed to furnish the means of calculating their resistance *a priori*, but upon attempting to establish the formula experimentally Hirn was unable to obtain the results which he anticipated. The memoir was submitted to the examination of Messrs. Folie, Van der Mensbrugghe and Melsens. The committee were unanimous in recommending its publication and in expressing the belief that its startling conclusions would be likely to awaken much profitable criticism and discussion, but Melsens was the only one who was prepared to adopt Hirn's conclusions and to admit that they would be likely to require a re-examination of some of the most important conclusions of thermodynamics. Hirn thinks that he has demonstrated that temperature has no influence upon the resistance of gases, that gaseous temperature and pressure cannot be explained by the movements of material atoms, and that it is impossible to give any satisfactory explanation of molecular phenomena without assuming an immediate dependence upon spiritual influence.—*Bull. de l'Acad. de Belge.* C.

Action of Light upon Oxygen.—J. Dessans has contrived an apparatus for governing the admission of the radiations from a Drummond light into a jar of oxygen, and he concludes, from experiments which he has frequently repeated, that light effects a direct transformation of oxygen into ozone. In the course of his experiments he sometimes used the oxygen as pure as possible, and in other cases he introduced substances which are easily oxidizable, so that they might readily combine with the ozone. Both methods of experimenting led to the same result.—*La Nature.* C.

Book Notices.

EXPERIMENTAL RESEARCHES INTO THE PROPERTIES AND MOTIONS OF FLUIDS, with theoretical deductions therefrom. By Mr. Ford Stanley. 8vo. London: E. & F. N. Spon, 1881.

One of the most elaborate and full studies, especially experimental, on this branch of physics to be found in English. Both in the collection of imperfectly known, and in the publication of entirely new and curious phenomena in minor experimentation, the book is unexampled.

In the latter regard some striking exhibitions are made. On page 72 is shown the extent of surface of disturbance of water by the effort of capillarity of tubes of various diameters by reflection from the water surface itself. On page 144 is shown how the general disturbance of a river current may be observed by a free circular floating tablet. On page 187 and following will be found a series of experimental yieldings of a minie ball, from the plasticity of its material—lead—against the resistance offered to its passage when discharged into water, by the mass of water, where the lead flattens and introverts itself into a coniod of hyperboloidal character approaching towards the whirl-ring which proceeds from a drop of colored water similarly but less forcibly projected into clear water—a series of illustrations ending in the rings which are deposited concentrically in the bottom of a shoal basin when consecutive drops of aniline solution are allowed to fall in still water. On page 238 the action of Venturi's cone in accelerating the velocity of an escaping jet is shown by a plane of discharge between flat glass plates with Venturi curves bounding the margins. Beside numerous

other interesting and pretty experiments. [The author is requested to test experiment, page 272, with one of the streams of colored water, when the writer thinks he will find the jets not to cross each other actually, but merely to do so apparently, and that it is a case of translation of motion.]

With all this nicety of experiments it cannot be said that the discussion of them in all cases reaches to theoretical deduction; frequently it scarcely passes the point of sentimental consideration. It may be admitted, with the author, that the theoretical, mathematical discussions of fluid properties and motions have not met happy solution on the supposition of linear movement in any vessel, tube or canal, and that the rolling effects (whirls) which, as far as we know, were first asserted by Darcy are the important, or at least *a* very important element to be investigated and reduced to *mathematical* expression. And it may be, also, that the *considerations* presented in this book have their place in indicating the direction of mathematical inquiry; but yet it is sure that we do not, as the result of Mr. Stanley's studies, come any nearer to the ability to form a correct theory of the motions of fluids than we were before. Weisbach, Rankine and Francis give practical results in better form for utility. It seems certain that their formula should have some different construction to be general, and that just such a study as this will show how to arrange or express them, only throughout this work no effort is made to go beyond the exhibition of phenomena in the direction of positive knowledge. The closest observation of the time-keeping qualities of a hundred watches would not of itself allow one to be made.

A writer in science is not at liberty to change an accepted name, because it does not express to his or to any mind most fully the property. Gelatinity is only a word. Viscosity expresses the internal resistance of a fluid quite as well, there might be an argument that it does better than gelatinity, but so long as the meaning is evident in the connection why not leave the word and pursue the study to the cause and not the name? Similarly, whirls and by-whirls, when vortexes are generally known. Possibly a theory of minor vortexes to explain the rolling or riband effects of surface contact might find a new name in by-whirls, when the mathematical exposition should complete the experimental development.

Passing from the narrative of observation which forms the first section or about one-half the book; to the "discussion of natural phenomena

in connection with previous propositions," it may be questioned if the *deductions* of Section I can be allowed as conclusive in governing the cosmic propositions of Section II. The writer of this notice thinks the author in common with many other book writers and storm authorities fails to appreciate the extreme thinness of the layers of atmosphere and of water in comparison to the superficial extent with which they have to deal and the enormous preponderance of local over general disturbances. Beside this, in the matter of aerial currents, there remains a remark of Sir John Leslie, seventy or eighty years since, on the positive direction of a current of air and the effect of the globular form of the earth when bodies in tangential movement crossed any locality. Together with some general assertion that a cloud or rain is at all times an ascending current, and clear weather a descending current of more or less intensity. On the whole it is hard to discern where the field of usefulness of this second section comes in, for it certainly lays down no laws of practical application.

Still the book must be recommended to students in physics as an extremely valuable contribution to science likely to awaken interest and induce study. R. B.

Franklin Institute.

Hall of the Institute, Feb. 15, 1882.

The stated meeting was called to order at 8 o'clock P.M.

There were present 122 members and 36 visitors.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers and announced that at the last meeting of the Board 10 persons were elected members of the Institute; he also reported that, by reason of the election of Mr. Frederick Graff to the office of Vice President, a vacancy was thereby created in the Board.

The Chemical Section presented its monthly report, which was read by the Secretary.

The President announced the first paper of the evening, by Mr. Grimshaw, on the determination of the "Driving Power of Belts." An abstract of his remarks, and the discussion thereon, will be found on page 174.

Mr. Lorin Blodget read a paper on "Silk Culture in the United States," for which see page 216.

At the request of Mr. Blodget the Secretary described the "Improved Silk Reel" of the Women's Silk Culture Association, designed and constructed by Mr. Hugo Bilgram, a member of the Institute. While there is no radical departure in its construction from the old forms of hand-reels, the new reel appears to embody every desirable feature that a hand-reel should possess. It is constructed entirely of metal (excepting the bars of the reel), and a skillful operator is enabled to reel upon it at least twice as much silk from the cocoons as upon the ordinary wooden hand-reels.

The report of the Secretary included a *resumé* of progress in Science and the Industrial Arts during the year 1881, and the exhibition and description of a number of mechanical and other novelties, the most notable of which were the following:

Maschmayer's T-Square; a movable blade square that can be clamped and held firmly in any position by means of thumb-screw, which draws a cone attached to the blade into a corresponding socket let into the head, and also lifts it out again when the blade is to be removed. This device was left for exhibition by Mr. L. G. Carr, of Philadelphia.

A similar device, of wood, with tapering blade, accomplishing the same object by substantially the same means, was also exhibited, as the design of Mr. William H. Thorne, Director of the Drawing School of the Institute.

Reed's Sectional Non-conducting Covering for Steam Pipes, Boilers and Water Pipes was shown in several forms. This covering is formed of compact felt represented to be made of the pulp of woolen rags. It is made in 3-feet sections, to fit any sized pipe, and in sheets for boilers, steam drums, etc., according to their size and shape. A saw cut is made the entire length of these sections, so that they may be forced open and sprung upon the pipe, and when in place the seam is fastened with copper staples. In making joints for a bend the sections are sawed off at the proper angle, and the edges of the joint attached as above. The covering is lined interiorly with asbestos, when desired; or an air space is provided, by using sections of larger diameter than the pipe to be covered, and supporting the ends of the sections on collars surrounding the pipe at suitable distances. Exhibited by Messrs. Bowen & Martin, of Philadelphia.

A number of specimens of Celluloid Stereotypes, consisting of

plates of type, engravings, and of impressions of natural objects, such as ferns and leaves, and of delicate fabrics, such as lace, were shown and described. They are intended as a substitute for the metal electrotypes and stereotypes now commonly used. The celluloid surface is represented to be well adapted for use in printing, on account of its hardness, toughness and elasticity. It is said to possess great wearing qualities and powers of resistance, and to be unaffected by acids, alkalies or other chemicals contained in printing inks, so that the plates can be employed with the most delicate shades of colored inks. Other advantages claimed for it are its ability to reproduce the finest lines of a cut or the finest type with accuracy, and its extreme lightness, which will be appreciated where large quantities of printing plates require to be handled and stored.

Wooden Type with Celluloid Face, of various sizes and styles, were shown. These are introduced as a superior substitute for wooden type. These novelties were exhibited by the Celluloid Stereotype Company, New York.

Several samples of mechanical lamps, of improved construction, with fixtures, were shown. They were adapted to burn petroleum or heavy animal oils without a chimney. In the petroleum lamps a blower, actuated by clock-work suitably disposed in the stem of the lamp, furnishes the air supply to the flame. In the lamp adapted for the animal oils the mechanism performs the double duty of furnishing the air supply and of delivering the oil to the wick tube by means of a pump. These were exhibited by the Hitchcock Lamp Company, Watertown, N. Y.

Samples of Cassava, and of products (starch, glucose, etc.) obtained from it were shown. The plant is represented to grow in great quantity in Florida, and it is claimed to be admirably adapted for the manufacture of glucose. The specimens were exhibited by Mr. Frank Higel.

A convenient Developing Lantern, for use in dry plate photography, was shown. It consists substantially of a rectangular tin box, with draught openings at top, and provided with a petroleum lamp, which can be rotated back and forth to face three sides of the rectangle. One face is provided with ruby glass for developing, and with a hood that can be drawn down to protect the eyes. A second face is furnished with a white porcelain pane, and the third with a plain glass window. The latter two are provided with doors, and are

designed respectively for examining the picture, and for printing by contact. This lantern was exhibited by the designer, Mr. John Carbutt, Philadelphia.

A very novel apparatus, in the form of an Opera Glass, that can be converted in a few minutes into a photographic apparatus, was also shown. It consisted of a complete dry plate outfit, adapted to an opera glass case. A matched pair of lenses (one having an instantaneous shutter) are quickly substituted in place of the usual eye pieces of the opera or field glass. The object glass of one tube is replaced by a plate of ground glass for focussing on, while in place of the object glass of the other tube a dry plate holder is easily attached. These changes have turned the opera glass into a photographic apparatus. It can then be directed towards the person or object to be photographed, and when the image is properly focussed on the ground glass the shutter on the other tube is sprung, and the picture is taken. A rolling spring screen then covers the sensitive plate, and it is transferred to the "dark chamber." This consists of a cylinder of black cloth, like a muff, into which the hands can be inserted, and which fits tightly about the wrists by means of elastic bands at both ends. In this the plate is removed and wrapped up, and another plate inserted in the holder for the next picture; the plate may be left until it can be conveniently developed at some future time. The apparatus is adapted to the use of tourists and detectives, and is made by R. & C. Avizard, Paris. It was exhibited by Mr. W. M. McAllister, Philadelphia.

The Norton Door Lock and Spring was described. It consists of a cylinder, piston, spring and adjustable valve. It is provided with two arms or levers, one of which is attached to the top of the door, the cylinder being connected with it by a hinged joint, and the other to the frame over the same. The spring furnishes the power necessary to close the door, and the valve, which can be adjusted to suit each particular case, provides an air cushion for the piston, thus closing the door quietly. This device was exhibited by H. A. Berry, of Philadelphia.

An Insertable Circular Saw Tooth, that can be attached to the saw plate by means of a key working in a wedge-shaped slot, and removed by pushing back the key, was shown. It was exhibited by Mr. A. J. Barrett.

Mr. G. Morgan Eldridge exhibited a model of Wilson P. Dodson's

Safety Switch for Railways, and described the same with the aid of the lantern. It consists substantially of a pair of guard rails, combined with fixed carrying rails in such a manner that they may be vibrated horizontally upon centres at or near their middle part, whereby an operative adjustment of both ends of the guard rails is obtained. The device was stated to have been in use for some months upon the South Mountain Railroad, near Carlisle, Pa., with satisfactory results.

Upon the announcement of the President that new business was in order, Mr. G. Morgan Eldridge moved that an election be held for a manager to fill the vacancy caused by the election of Mr. Frederick Graff to the Vice Presidency. A ballot was taken, and the tellers announced the election of Mr. C. Chabot, to fill the unexpired term of Mr. Graff.

The President named the following Standing Committees of the Institute for 1882:

On the Library.—Chas. Bullock, Lewis S. Ware, Dr. Isaac Norris, Robert Briggs, Henry Bower, Henry Pemberton, J. E. Mitchell, Jos. M. Wilson, Fred. Graff, Dr. W. Lehman Wells.

On Minerals.—Dr. F. A. Genth, Theo. D. Rand, Clarence Bement, Persifor Frazer, Dr. W. H. Wahl, E. J. Houston, Otto Lüthy, E. F. Moody, Dr. G. A. Koenig, H. Pemberton, Jr.

On Models.—C. Chabot, H. L. Butler, Edward Brown, M. L. Orum, J. Goehring, L. L. Cheney, J. J. Weaver, S. Lloyd Wiegand, A. G. Busby, N. H. Edgerton.

On Arts and Manufactures.—J. J. Weaver, George V. Cresson, Hector Orr, Coleman Sellers, Jr., W. B. LeVan, Wm. Helme, J. S. Bancroft, Alfred Mellor, Cyrus Chambers, Jr., Geo. Burnham.

On Meteorology.—Pliny E. Chase, Hector Orr, Dr. Isaac Norris, David Brooks, Jas. A. Kirkpatrick, Alex. Purves, Dr. W. H. Wahl, F. M. M. Beale, H. Carvill Lewis.

On Meetings.—Fred. Graff, Washington Jones, Chas. H. Banes, A. E. Outerbridge, Jr., W. L. Dubois, W. H. Thorne, Cyrus Chambers, Jr., J. J. Weaver, Addison B. Burk.

On motion, the Institute adjourned.

William H. Wahl, *Secretary.*

JOURNAL

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A NEW THEORY OF THE SUSPENSION SYSTEM WITH STIFFENING TRUSS.

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ORDINARY METHOD INCORRECT.

The usual method adopted for the discussion of the stiffening girder is to assume that the truss distributes any partial load over the cable, *so as to cause it to take effect as a uniform load.* The new curve of the cable is thus assumed to be still a parabola, with its vertex at the centre, whatever may be the loading. By finding, then, the deflections at centre of cable and truss, and equaling them, that portion of the partial load which acts on the cable as a uniformly distributed load is easily found. This is the same as the upward load on the truss. The moment at any point of the truss can then be determined.

This method is, however, essentially incorrect. The truss, it is true, does act to distribute any partial load over the cable, but we have no right to assume this distributed load is uniform. In point of fact it is not uniform. The new curve of the cable is not a parabola

whose vertex is at the centre, but it is a curve similar to that shown in Fig. 8. The distributed load on the cable is therefore *not* uniform, but follows some other law of distribution.

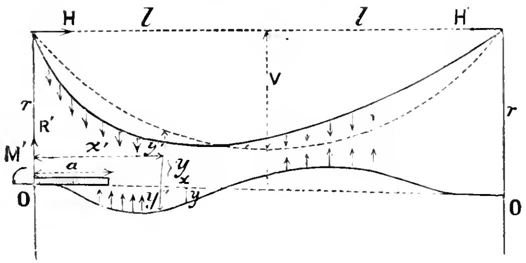

Fig. 8.

This distributed load, whatever its law may be, acts through the suspenders as an equal upward load upon the truss. The elastic curve of the truss is then similar to that shown in Fig. 8. If we neglect the slight increase of length of the suspenders, we can assume that *the deflections of truss and cable at any point are equal.*

Notation.

Let the moving load per unit of length be m, and let this load extend over a distance, a, from the left end. Let R_1 be the reaction at the left end, *positive* when it acts upwards, and M_1 be the moment at the left end. Any moment tending to cause compression in the upper flange is *positive.* Take O, Fig. 8, as the origin of co-ordinates. For any point distant x_1 from the left end, let y' be the ordinate to the *original* curve of ccable. x_1 is positive towards the right, and y' is positive when laid off above OO'. Let the deflection of the truss at the same point x_1 be y''. y'' is also positive when laid off *above* OO'. Let Y be the ordinate at the same point x_1 of the *new* curve of cable. Then at any point x_1 we have generally

$$Y = y' + y'' \tag{27}$$

Let x be any point of the truss on the right of x_1 and y be the corresponding deflection. Let v, as always, be the versine of original curve of cable, and r the height of tower, and l the half span.

Moment of Distributed Cable Load.

Since the curve of the cable is originally a parabola, under the action of the entire dead load, which may be considered as uniform,

its equation is easily found from (10), by transferring the origin from the centre to O,

$$y' = r - \frac{2\,v\,x_1}{l} + \frac{r\,x_1^{\,2}}{l^2}$$

We have then from (27)

$$Y = r - \frac{2\,v\,x_1}{l} + \frac{r\,x_1^{\,2}}{l^2} + y''$$

for the ordinate to new curve of cable at any point x_1, y'' being negative when below horizontal.

The tangent of the angle of inclination with horizontal of the new curve of cable at any point x_1 is then

$$\frac{d\,Y}{d\,x_1} = -\frac{2\,v}{l} + \frac{2\,r\,x_1}{l^2} + \frac{d\,y''}{d\,x_1} \qquad (28)$$

The new curve is an equilibrium curve. Its horizontal force at all points is therefore constant. Let this constant horizontal force, or pull of cable, be H.

Then $H\,\dfrac{d\,Y}{d\,x_1}$ is the vertical force at any point. The differential of this will give the elementary load on cable at any point x_1,

$$H\,\frac{d^2\,Y}{d\,x_1^{\,2}}\,d\,x_1 = H\,\frac{2\,v}{l^2}\,d\,x_1 + H\,\frac{d^2\,y''}{d\,x_1^{\,2}}\,d\,x_1 \qquad (29)$$

The moment of this elementary load with reference to any point x on the right of x_1, is $H\,\dfrac{d^2\,Y}{d\,x_1^{\,2}}\,d\,x_1\,(x - x_1)$

Therefore
$$\int_{x_1=0}^{x_1=x} H\,\frac{d^2\,Y}{d\,x_1^{\,2}}\,d\,x_1\,(x - x_1) = \text{moment of entire distributed}$$

load on cable between left end and any point x_1 with reference to x.

We have then from (29)

$$\int_{x_1=0}^{x_1=x} H\,\frac{d^2\,Y}{d\,x_1^{\,2}}\,d\,x_1\,(x - x_1) = \int_{x_1=0}^{x_1=x} H\,x\,\frac{d^2\,Y}{d\,x_1^{\,2}}\,d\,x_1 - \int_{x_1=0}^{x_1=x} H\,\frac{d^2\,Y}{d\,x_1^{\,2}}\,x_1\,d\,x_1$$

$$= H\int_{x_1=0}^{x_1=x} \frac{2v\,x}{l^2}\,d\,x_1 + H\int_{x_1=0}^{x_1=x} x\,\frac{d^2\,y''}{d\,x_1^{\,2}}\,d\,x_1 - H\int_{x_1=0}^{x_1=x} \frac{2\,v}{l^2}\,x_1\,d x_1 - H\int_{x_1=0}^{x_1=x} \frac{d^2\,y''}{d\,x_1^{\,2}}\,x_1\,d x_1$$

Performing the integrations, we have, since when $x_1 = 0$, $\frac{d^2 y''_0}{d\ x_1^2} = 0$, if the truss is fixed horizontally at the ends,

$$\int_{x_1=0}^{x_1=x} H \frac{d^2 Y}{d x_1^2} d x_1 (x - x_1) = H \frac{2 v x^2}{l^2} + H x \frac{dy}{dx} - H \frac{v x^2}{l^2} - H \int_{x_1=0}^{x_1=x} \frac{d^2 y''}{d\ x_1^2} x_1 d x_1$$

$$= H \frac{v\ x^2}{l^2} + H\ x \frac{dy}{dx} - H \int_{x_1=0}^{x_1=x} \frac{d^2 y''}{d\ x_1^2} x_1\ d x_1 \qquad (30)$$

Let us now consider the final integral in equation (30).

We have from the differential calculus

$$d\ (x\ y) = x\ dy + y\ dx$$

hence

$$x\ dy = d\ (x\ y) - y\ dx$$

Now let $x = x_1$ and $y = \frac{d\ y''}{d\ x_1}$. Then $d\ y = \frac{d^2\ y''}{d\ x_1^2} d x_1$ and $x\ dy = \frac{d^2\ y''}{d\ x_1^2} x_1\ d x_1$

$$\text{Hence} \int_{x_1=0}^{x_1=x} \frac{d^2\ y''}{d\ x_1^2} x_1\ d x_1 = H \int_{x_1=0}^{x_1=x} d \left[\frac{d\ y''}{d\ x_1} x_1\right] - H \int_{x_1=0}^{x_1=x} \frac{d\ y''}{d\ x_1} d\ x_1$$

Performing the integration and remembering that when $x_1 = 0$, $y'' = 0$ and $\frac{d\ y''}{d\ x_1} = 0$, we have

$$H \int_{x_1=0}^{x_1=x} \frac{d^2\ y''}{d\ x_1^2} x_1\ d\ x = H\ x \frac{dy}{dx} - H\ y$$

Substituting this in (30) we have

$$\int_{x_1=0}^{x_1=x} H \frac{d^2\ Y}{d\ x_1^2} d\ x_1\ (x - x_1) = H \frac{v\ x^2}{l^2} + H\ y \qquad (31)$$

Equation (31) gives the moment of the entire distributed cable load between the left end and any point distant x from the left end, with reference to that point as a centre of moments.

Elastic Curve of the Truss.

From the theory of flexure we have for the differential equation of the elastic curve the moment at any point from $x = 0$ to $x = a$, or when $x < a$

$$E\,I\,\frac{d^2\,y}{d\,x^2} = R_1\,x - \frac{m\,x^2}{2} + \frac{H\,v\,x^2}{l^2} + H\,y + M_1 \tag{32a}$$

For any point from $x = 2\,l$ to $x = a$, or when $x > a$

$$E\,I\,\frac{d^2 y_1}{d\,x^2} = R_1(x-2l) - ma(x-2l) + \frac{H\,v}{l^2}(x^2-4l^2) + Hy_1 + M_2 \tag{32b}$$

where $M_2 = 2\,R_1\,l - m\,a\left(2\,l - \frac{a}{2}\right) + 4\,H\,v + M_1$

where y_1 denotes the deflection at any point beyond the load.

If we differentiate equation (32a) twice, we have

$$E\,I\,\frac{d^3\,y}{d\,x^3} = R_1 - m\,x + \frac{2\,Hvx}{l^2} + H\,\frac{dy}{dx} \tag{33a}$$

$$E\,I\,\frac{d^4\,y}{d\,x^4} = \frac{2\,Hv}{l^2} + H\,\frac{d^2\,y}{d\,x^2} - m \tag{34a}$$

Equation (34a) can be put in simple shape. Thus let

$$\left.\begin{aligned} H\,\tau^2 &= E\,I \\ z &= \frac{2\,v}{l^2} + \frac{d^2\,y}{d\,x^2} - \frac{m}{H} \end{aligned}\right\} \tag{35a}$$

Then

$$\frac{d\,z}{dx} = \frac{d^3\,y}{d\,x^3},\quad \frac{d^2\,z}{d\,x^2} = \frac{d^4\,y}{d\,x^4}$$

and equation (34a) becomes

$$\frac{d^2\,z}{d\,x^2} = \frac{z}{\tau^2} \tag{36a}$$

Integrating* between the limits $x = o$ and x_1 we have

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* The integration is performed as follows:

$$\frac{d^2\,z}{dx^2} = \frac{z}{\tau^2}$$

Multiply both sides by $2\,d\,z$, then

$$\frac{2\,d\,z\,d^2\,z}{d\,x^2} = \frac{2\,z\,d\,z}{\tau^2}$$

$$\text{Integrating}\quad \frac{d\,z^2}{d\,x^2} = \frac{z^2}{\tau^2} + C_1 \tag{1}$$

Now in the present case, when $x = o$ $\frac{d\,y}{d\,x} = o$ and from (33a) $\frac{dz^2}{dx^2} = \left(\frac{d^3y}{dx^3}\right)^2 =$

$$z = A\,e^{\frac{x}{\tau}} - B\,e^{-\frac{x}{\tau}} \tag{37a}$$

where e is the base of the Naperian system of logarithms, or $e = 2{\cdot}7182818$ and A and B are constants of integration to be determined by the special conditions of the case.

In the present case

$\frac{R_1^2}{H^2\,\tau^4}$. Also when $x = o$, $y = o$ and from (32a) $\frac{d^2y}{dx^2} = \frac{M_1}{H\tau^2}$. Hence for $x = o$,

$$\frac{z^2}{\tau^2} = \frac{\left(\frac{2\,v}{l^2} - \frac{m}{H} + \frac{M_1}{H\,\tau^2}\right)^2}{\tau^2}$$

Hence
$$C_1 = \frac{R_1^2}{H^2\,\tau^4} - \frac{\left(\frac{2\,v}{l^2} - \frac{m}{H} + \frac{M_1}{H\,\tau^2}\right)^2}{\tau^2} \tag{2}$$

From (1) we have $d\,x = \frac{d\,z}{\sqrt{\frac{z^2}{\tau^2} + C_1}}$

Integrate again and we have

$$x = \tau\,\log.\left[\frac{z}{\tau} + \sqrt{\frac{z^2}{\tau^2} + C_1}\right] + C_2 \tag{3}$$

In the present case, for $x = o$ we have

$$C_2 = -\,\tau\,\log.\left[\frac{\frac{2\,v}{l^2} - \frac{m}{H} + \frac{M_1}{H\tau^2}}{\tau} + \frac{R_1}{H\tau^2}\right] \tag{4}$$

From (3) we have

$$e^{\frac{x - C_2}{\tau}} - \frac{z}{\tau} = \sqrt{\frac{z^2}{\tau^2} + C_1} \quad \text{or} \quad z = \frac{\tau}{2}\left(e^{\frac{x - C_2}{\tau}} - C_1\,e^{-\frac{x - C_2}{\tau}}\right)$$

Put $A = \frac{\tau}{2}\,e^{-\frac{C^2}{\tau}}$ and $B = \frac{\tau}{2}\,C_1\,e^{\frac{C^2}{\tau}}$ and we have

$$z = A\,e^{\frac{x}{\tau}} - B\,e^{-\frac{x}{\tau}}$$

which is the equation in the text.

From (4) we have

$$e^{-\frac{C^2}{\tau}} = \frac{R_1}{H\tau^2} + \frac{\frac{2\,v}{l^2} - \frac{m}{H} + \frac{M_1}{H\tau^2}}{\tau}$$

Hence

$$A = \tfrac{1}{2}\left[\frac{R_1}{H\,\tau} + \left(\frac{2\,v}{l^2} - \frac{m}{H} + \frac{M_1}{H\tau^2}\right)\right]$$
$$B = \tfrac{1}{2}\left[\frac{R_1}{H\,\tau} - \left(\frac{2\,v}{l^2} - \frac{m}{H} + \frac{M_1}{H\tau^2}\right)\right]$$

$$\left.\begin{array}{ll} A = \frac{1}{2}[K + N] & B = \frac{1}{2}[K - N] \\ K = \dfrac{R_1}{H\tau} & N = \dfrac{2v}{l^2} - \dfrac{m}{H} + \dfrac{M_1}{H\tau^2} \end{array}\right\} \qquad (38a)$$

From (37a) we have, after replacing z by its value in (35a)

$$\frac{d^2 y}{d x^2} = A\, e^{\frac{x}{\tau}}\ B\, e^{-\frac{x}{\tau}} - \frac{2v}{l^2} + \frac{m}{H} \qquad (39a)$$

Differentiating (39a) twice, we have

$$\frac{d^3 y}{d x^3} = \frac{A}{\tau} e^{\frac{x}{\tau}} + \frac{B}{\tau} e^{-\frac{x}{\tau}} \qquad (40a)$$

$$\frac{d^4 y}{d x^4} = \frac{A}{\tau^2} e^{\frac{x}{\tau}} - \frac{B}{\tau^2} e^{-\frac{x}{\tau}} \qquad (41a)$$

We have also by integration, from (39a)

$$\frac{dy}{dx} = \tau\, A\, e^{\frac{x}{\tau}} + \tau\, B\, e^{-\frac{x}{\tau}} - \frac{2\, v\, x}{l^2} + \frac{m\, x}{H} + C \qquad (42a)$$

when $x = o$, $\dfrac{dy}{dx} = o$ and hence

$$C = -\tau\,(A + B) = -\frac{R_1}{H} \qquad (43a)$$

Also

$$y = \tau^2\, A\, e^{\frac{x}{\tau}} - \tau^2\, B\, e^{-\frac{x}{\tau}} - \frac{v\, x^2}{l^2} + \frac{m\, x^2}{H} + C\, x + D \qquad (44a)$$

when $x = o$, $y = o$ and hence

$$D = -\tau^2\,(A - B) = -\tau^2 \left(\frac{2v}{l^2} - \frac{m}{H} + \frac{M_1}{H\tau^2}\right) \qquad (45a)$$

The values of all the constants are thus given in terms of H_1, M_1 and R_1, which still remain to be found.

For that portion of the elastic curve beyond the load, equation (32b) holds good. Differentiate this twice and we have

$$E\, I\, \frac{d^3\, y_1}{d\, x^3} = R_1 - m\, a + \frac{2\, H\, v\, x}{l^2} + H\, \frac{d\, y_1}{d\, x_1} \qquad (33b)$$

$$E\, I\, \frac{d^4\, y_1}{d\, x^4} = \frac{2\, H v}{l^2} + H\, \frac{d^2\, y_1}{d\, x^2} \qquad (34b)$$

Equation (34b) can be put in a simpler shape. Thus, let, as before,

$$\left.\begin{aligned} H\tau^2 &= E\,I \\ \text{and}\quad z_1 &= \frac{2\,v}{l^2} + \frac{d^2\,y_1}{d\,x^2} \end{aligned}\right\} \tag{35b}$$

Then equation (34*b*) becomes

$$\frac{d^2\,z_1}{d\,x^2} = \frac{z_1}{\tau^2} \tag{36b}$$

Integrating between the limits $x = 2\,l$ and x, we have

$$z_1 = \alpha\,e^{\frac{x-2\,l}{\tau}} - \beta\,e^{-\frac{x-2\,l}{\tau}} \tag{37b}$$

where, as before, e is the base of the Naperian system of logarithms, and α and β are constants of the integration, to be determined by the special conditions of the case.

In the present case

$$\left.\begin{aligned} \alpha &= \frac{\tau}{2}\left(\eta + \varphi\right) \quad \beta = \frac{\tau}{2}\left(\eta - \varphi\right) \\ \eta &= \frac{R_1 - m\,a + \dfrac{4\,H\,v}{l}}{H\,\tau^2} \\ \varphi &= \frac{2\,v}{\tau\,l^2} + \frac{2\,R_1\,l - m\,a\left(2\,l - \dfrac{a}{2}\right) + 4\,H\,v + M_1}{H\,\tau^3} \end{aligned}\right\} \tag{38b}$$

From (37*b*) we have, after replacing z by its value in (35*b*),

$$\frac{d^2 y_1}{d\,x^2} = \alpha\,e^{\frac{x-2\,l}{\tau}} - \beta\,e^{-\frac{x-2\,l}{\tau}} - \frac{2\,v}{l^2} \tag{39b}$$

From (39*b*) by differentiating twice, we have

$$\frac{d^3\,y_1}{d\,x_3} = \frac{\alpha}{\tau}\,e^{\frac{x-2\,l}{\tau}} + \frac{\beta}{\tau}\,e^{-\frac{x-2\,l}{\tau}} \tag{40b}$$

$$\frac{d^4\,y_1}{d\,x^4} = \frac{\alpha}{\tau^2}\,e^{\frac{x-2\,l}{\tau}} - \frac{\beta}{\tau}\,e^{-\frac{x-2\,l}{\tau}} \tag{41b}$$

We have also from (39*b*) by integration between the limits $2\,l$ and x,

$$\frac{d\,y_1}{d\,x} = \tau\,\alpha\,e^{\frac{x-2\,l}{\tau}} + \tau\,\beta\,e^{-\frac{x-2\,l}{\tau}} - \frac{2\,v}{l^2}\,(x-2l) + \gamma \tag{42b}$$

when $x = 2\,l,\ \frac{d\,y_1}{d\,x} = o$ and

$$\gamma = -\tau\,(\alpha + \beta) = -\tau^2\,\eta \tag{43b}$$

Integrating again

$$y_1 = \tau^2\,\alpha\,e^{\frac{x-2\,l}{\tau}} - \tau^2\,\beta\,e^{-\frac{x-2\,l}{\tau}} - \frac{v}{l^2}\,(x-2\,l)^2 +$$

$$\gamma\,(x-2\,l + \delta \tag{44b}$$

when $x = 2\,l,\ y_1 = o$ and

$$\delta = -\tau^2\,(\alpha - \beta) = -\tau^3\,\varphi \tag{45b}$$

Equation (44*a*) gives the elastic curve of that portion of the truss covered by the load, and (44*b*) of all that portion beyond the load.

All the constants, A, B, C, D and α, β, γ, δ, are given in terms of R_1, M_1 and H. It remains to determine these quantities.

Value of H, R_1 and M_1.

At the point where $x = a$, the two portions of the elastic curve, right and left, have the same deflection and a common tangent. Also the moment and shear at this point are the same for both curves. Hence for $x = a$, equations (44*b*) and (44*a*), (42*b*) and (42*a*), (40*b*) and (40*a*), (41*b*) and (41*a*) are simultaneous.

We have then the following equations of condition:

$$\tau^2\,A\,e^{\frac{a}{\tau}} - \tau^2\,B\,e^{-\frac{a}{\tau}} - \frac{v\,a^2}{l^2} + \frac{m\,a^2}{2\,H} + C\,a + D = \tau^2\,\alpha\,e^{\frac{a-2\,l}{\tau}}$$

$$-\tau^2\,\beta\,e^{-\frac{a-2\,l}{\tau}} - \frac{v}{l^2}\,(a-2\,l)^2 + \gamma\,(a-2\,l) + \delta \tag{a}$$

$$\tau\,A\,e^{\frac{a}{\tau}} + \tau\,B\,e^{-\frac{a}{\tau}} - \frac{2\,v\,a}{l^2} + \frac{m\,a}{H} + C = \tau\,\alpha\,e^{\frac{a-2\,l}{\tau}}$$

$$-\tau\,\beta\,e^{-\frac{a-2\,l}{\tau}}\ \frac{2\,v}{l^2}\,(a-2\,l) + \gamma \tag{b}$$

$$A\,e^{\frac{a}{\tau}} - B\,e^{-\frac{a}{\tau}} + \frac{m}{H} = \alpha\,e^{\frac{a-2\,l}{\tau}} - \beta\,e^{-\frac{a-2\,l}{\tau}} \tag{c}$$

$$\frac{A}{\tau}\,e^{\frac{a}{\tau}} + \frac{B}{\tau}\,e^{-\frac{a}{\tau}} = \frac{\alpha}{\tau}\,e^{\frac{a-2\,l}{\tau}} + \frac{\beta}{\tau}\,e^{-\frac{a-2\,l}{\tau}} \tag{d}$$

Combining (c) and (d) by addition and subtraction, we obtain

$$\left.\begin{aligned} 2\,A\,e^{\frac{a}{\tau}} - 2a\,e^{\frac{a-2\,l}{\tau}} &= -\frac{m}{H} \\ 2\,\beta\,e^{-\frac{a-2\,l}{\tau}} - 2\,B\,e^{-\frac{a}{\tau}} &= -\frac{m}{H} \end{aligned}\right\} \quad \text{(XVI)}$$

Combining (a) and (b) in the same way, we have after substituting the values of C, D, γ and δ, from (43a), (45a), (43b) and (45b), and reducing, precisely the same two equations as (XVI). In like manner the combination of (b) and (c) gives us precisely the same two equations. So also for the combination of (a) and (d).

Our four equations of condition give us then in reality only two equations containing R_1, M_1, and H or τ.

It is necessary to find a third equation. This we can easily do, by assuming, in accordance with the ordinary theory, that the curve of the cable remains parabolic even for partial loading. Although this assumption is not theoretically correct, still, in practice, the real curve differs so little from the parabolic, that, *so far as the cable alone is concerned,* the value of H thus found is very exactly the real value of H.

We have then

$$H = \frac{k\,m\,l^2}{2\,v} \quad \text{(XVII)}$$

where we have already found for k the values:

when $a < l$

$$k = \frac{a^3\,(2\,l-a)}{2\,l^4\left[1 + \frac{9\,E_2\,F_2\,h^2}{4\,E_1\,F_0\,v^2}\right]} \quad \text{(VIII)}$$

when $a > l$

$$k = \frac{2\,l^4 - a\,(2\,l - a)^3}{2\,l^4\left[1 + \frac{9\,E_2\,F_2\,h^2}{4\,E_1\,F_0\,v^2}\right]} \quad \text{(VIII}a\text{)}$$

If we put for I_2 its value, viz., $I_2 = F_2\,\frac{h^2}{4}$ we have

$$\tau = \sqrt{\frac{E_2\,F_2\,h^2\,v}{2\,k\,m\,l^2}} \quad \text{(XVIII)}$$

These values of τ and H, inserted in equations (XVI), will give us two equations containing only R_1 and M_1. We can therefore find

these quantities. Thus, the values of H, τ, R_1 and M_1 can be easily determined for any given value of a.

Temperature Load.

The effect of a rise of temperature of t° above the mean, is to load the truss with a uniform downward load, or "hot load" of q per unit of length. A fall of temperature of t° below the mean causes an equal uniformly distributed upward load, or "cold load." In either case we have already found

$$q = \frac{2\,\varepsilon\,t\,E_1\,F_0\,v}{l^2\left[1 + \frac{9\,E_1\,F_0\,v^2}{4\,E_2\,F_2\,h^2}\right]} \tag{VI}$$

The moment then at any point of the truss due to the temperature load is

$$M_x = q\,l\,x - \frac{q\,x^2}{2} - \frac{q\,l^2}{3} \tag{XIX}$$

and the shear at any point is

$$S_x = q\,l - q\,x \tag{XX}$$

The strains due to each case of temperature load must be combined with those due to live load, so as to give the greatest possible strains.

Recapitulation of Formulæ Necessary for Complete Calculation of Truss.

For convenience of reference we group here all the formulæ thus far deduced, which are requisite for the calculation of the truss, in the order in which they must be used

$$\text{approx. } F_0 = \frac{(p+m)l^2}{2vf_1}\left(1+\frac{2v^2}{l^2}\right) \tag{IX}$$

$$\text{approx. } F_1 = \frac{(p+m)l^2}{2vf_1}\,. \tag{IXa}$$

$$\text{approx. } q = \frac{2\varepsilon t E_1 F_0 v}{l^2\left(1+\frac{4E_1v^2}{9E_2h^2}\right)} \tag{24}$$

$$\text{approx. } n = \frac{1}{1+\frac{9E_2h^2}{4E_1v^2}} \tag{23}$$

$$\text{approx. } F_2 = \frac{[(1-n)m+q]l^2}{3hf_2} \qquad \text{(X)}$$

These approximate values, being found, the accurate values are

$$n = \frac{1}{1+\dfrac{9E_2F_2h^2}{4E_1F_0v^2}} \qquad \text{(VII)}$$

$$q = \frac{2\varepsilon tE_1F_0v}{l^2\left[1+\dfrac{4E_1F_0v^2}{9E_2F_2h^2}\right]} \qquad \text{(VI)}$$

$$F_1 = \frac{(p+nm+q)l^2}{2vf_1} \qquad \text{(XV)}$$

$$F_0 = \frac{(p+nm+q)l^2}{2vf_1}\left(1+\frac{2v^2}{l^2}\right) \qquad \text{(XIV)}$$

For varying cross-section of cable, put F_1 in place of F_0, in (VII) (VI).

We can now find

$$\tau = \sqrt{\frac{E_2F_2h^2}{2kml^2}} \qquad \text{(XVIII)}$$

where k is given by,
when $a < l$

$$k = \frac{a^3(2l-a)}{2l^4\left[1+\dfrac{9E_2F_2h^2}{4E_1F_0v^2}\right]} \qquad \text{(VIII)}$$

when $a > l$

$$k = \frac{2l^4-a(2l-a)^3}{2l^4\left[1+\dfrac{9E_2F_2h^2}{4E_1F_0v^2}\right]} \qquad \text{(VIIIa)}$$

Also

$$H = \frac{kml_2}{2v} \qquad \text{(XVII)}$$

In these values for k, put F_1 in place of F_0 for varying cross-section of cable.

Knowing now, τ and H, we can substitute their values in

$$\left.\begin{aligned} 2Ae^{\frac{a}{\tau}} - 2ae^{\frac{a-2l}{\tau}} &= -\frac{m}{H} \\ 2\beta e^{-\frac{a-2l}{\tau}} - 2Be^{-\frac{a}{\tau}} &= -\frac{m}{H} \end{aligned}\right\} \qquad \text{(XVI)}$$

Where

$$\left.\begin{aligned} A &= \frac{1}{2}\left[\frac{R_1}{H\tau} + \left(\frac{2v}{l^2} - \frac{m}{H} + \frac{M_1}{H\tau_2}\right)\right] \\ B &= \frac{1}{2}\left[\frac{R_1}{H\tau} - \left(\frac{2v}{l^2} - \frac{m}{H} + \frac{M_1}{H\tau^2}\right)\right] \end{aligned}\right\} \tag{38a}$$

And

$$\left.\begin{aligned} \alpha &= \frac{\tau}{2}\left(\eta + \varphi\right) \qquad \beta = \frac{\tau}{2}\left(\eta - \varphi\right) \\ \eta &= \frac{R_1 - ma + \dfrac{4Hv}{l}}{H\tau^2} \\ \varphi &= \frac{2v}{\tau l^2} + \frac{2R_1 l - ma\left(2l - \dfrac{a}{2}\right) + 4Hv + M_1}{H\tau^3} \end{aligned}\right\} \tag{38b}$$

R_1 M_1, H and T being thus found, we can find the deflection at any point from the following equations:

when $x < a$

$$y = \tau^2 Ae^{\frac{x}{\tau}} - \tau^2 Be^{-\frac{x}{\tau}} - \frac{vx^2}{l^2} + \frac{mx^2}{2H} + Cx + D \tag{44a}$$

where

$$C = -\frac{R_1}{H}, \quad D = -\tau^2 (A - B)$$

when $x > a$

$$y_1 = \tau^2 \alpha e^{\frac{x-2l}{\tau}} - \tau^2 \beta e^{-\frac{x-2l}{\tau}} - \frac{v}{l^2}(x-2l)^2 + \gamma(x-2l) + \delta \tag{44b}$$

$$\text{where } \gamma = -\tau^2\eta \quad \delta = -\tau^3\varphi$$

Having thus found y, we can find the moment at any point from the following equations:

When $x < a$

$$M_x = R_1 x - \frac{mx^2}{2} + \frac{Hvx^2}{l^2} + Hy + M_1 \tag{32a}$$

When $x > a$

$$M_x = R_1 x - ma\left(x - \frac{a}{2}\right) + \frac{Hvx^2}{l^2} + Hy_1 + M_1 \tag{32b}$$

Finally, the shear at any point is given by the following equations:
When $x < a$

$$S_x = R_1 - mx + \frac{2Hrx}{l^2} + H\frac{dy}{dx} \qquad (33a)$$

When $x > a$

$$S_x = R_1 - ma + \frac{2Hr}{l^2} + H\frac{dy_1}{dx_1} \qquad (33b)$$

Where

$$\frac{dy}{dx} = \tau A e^{\frac{x}{\tau}} + \tau B e^{-\frac{x}{\tau}} - \frac{2rx}{l^2} + \frac{mx}{H} + C \qquad (42a)$$

$$\frac{dy_1}{dx} = \tau \alpha e^{\frac{x-2l}{\tau}} + \tau \beta e^{-\frac{x-2l}{\tau}} - \frac{2r}{l^2}\left(x - 2l\right) + \gamma \qquad (42b)$$

For temperature load we have

$$q = \frac{2\varepsilon t E_1 F_0 r}{l^2\left[1 + \frac{9E_1F_0r^2}{4E_2F_2h^2}\right]} \qquad (VI)$$

Where for varying cross-section of cable we put F_1 in place of F_0.
The moment at any point is then

$$M_x = qlx - \frac{qx^2}{2} - \frac{ql^2}{3} \qquad (XIX)$$

and the shear is

$$S_x = ql - qx. \qquad (XX)$$

Calculation of Strains.

These are all the formulæ necessary for finding the strains in the truss.

Thus we can first find the temperature strains from (VI), XX) and (XXI). Thus the moment at the centre of any flange, divided by the depth of truss, gives the strain in the flange. A negative moment denotes tension in the upper flange. A positive moment compression.

The shear at any apex multiplied by the secant of the angle which the brace makes with the vertical, gives the strain in the brace. A positive shear acts upward at the left end of the brace. A negative shear acts downward at the left end of the brace.

The strains thus found for temperature load may be of either kind for each piece, according as the "cold load" or "hot load" acts, but in each case is equal in amount.

For the moving load it will be sufficient to take a for a few points of the truss; thus $a = \frac{1}{8}l, \frac{2}{8}l, \frac{3}{8}l$, etc. For each value of a, find the moments at a few points, such as $x = o, \frac{1}{8}l, \frac{2}{8}l$, etc. Also the shears. We can then plot these moments and shears to scale. Thus in Fig. 9, we can plot the curves of moments for $a = \frac{1}{8}l, \frac{2}{8}l$, etc. Then

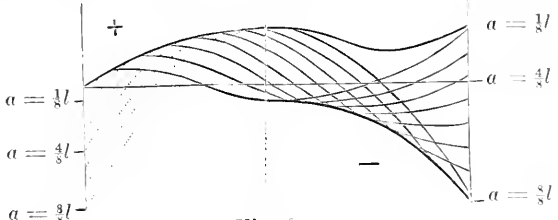


Fig. 9.

at any point the maximum moment will be given by the greatest ordinate at that point to any one of these curves. The curve enveloping them all will therefore give the maximum moments. Thus, in Fig. 9, the greatest positive moment at any point in the right hand half of truss is given by the ordinates to the upper enveloping curve on *right*. The greatest negative moments by ordinates to lower enveloping curve on *right*. The strains in each half are of course the same.

We may treat the shears in similar manner. The maximum moments and shears being found, we can find the corresponding strains as detailed for temperature load.

ADAPTATION OF EULER'S FORMULA TO AMERICAN LONG COLUMN EXPERIMENTS.

By Wm. H. Burr,

Professor of Rational and Technical Mechanics in Rensselaer Polytechnic Institute.

There are some considerations in connection with long column formulæ which frequently escape notice, but which have a very important bearing upon the subject.

Let the following notation be considered:

P = total load, in pounds, supported by column.

S = total area of cross section of column, in square inches.

r = radius of gyration about the neutral axis of the section.

l = length of column in same unit as r.

E = coefficient of elasticity, in pounds per square inch.

Then may Euler's formula become:

$$\frac{P}{S} = p = \frac{4\pi^2 E r^2}{l^2} \text{ (for fixed ends).} \tag{1}$$

With Hodgkinson's coefficients and exponents this is called "Hodgkinson's Formula."

If p'' is the greatest intensity of compressive bending stress in the column, there may be written, by the aid of equation (1):

$$p'' = p'' \frac{P}{S} \frac{l^2}{4\pi^2 E r^2} \tag{2}$$

Adding p to both sides of equation (2), and representing the greatest intensity of compression, allowable in the column, by f:

$$f = p'' + p = \frac{P}{S}\left(1 + \frac{p''}{4\pi^2 E} \cdot \frac{l^2}{r^2}\right)$$

$$\therefore \frac{P}{S} = p = \frac{f}{1 + \frac{p''}{4\pi^2 E} \cdot \frac{l^2}{r^2}} \tag{3}$$

This is the general form of Tredgold's equation. If $\frac{p''}{4\pi^2 E}$ is considered constant and empirical, it is called Gordon's or Rankine's formula, as the latter was the first to introduce the radius of gyration.

Under the gratuitous assumption that $p'' \div 4\pi^2 E$ is constant, it has been empirically determined for different forms of cross section, and inserted in equation (3).

With f determined in a similar manner, equation (3) becomes the long column formula in general use among engineers, and is usually written:

$$P = \frac{f S}{1 + a \frac{l^2}{r^2}} \tag{4}$$

But it has just been shown that a is *not* a constant, and the preceding operations also show that equation (4), or equation (3), is simply a redundant form of equation (1) or Euler's formula. It would therefore be natural to expect that equation (1) would give results more nearly coinciding with those of experiment than equation (3) or equation (4).

If, however, C is the ultimate compressive resistance of the material, equation (1) becomes inapplicable when $r^2 \div l^2$ is so large that $\frac{P}{S}$ approaches C; or, at the limit, when:

$$\frac{l}{r} \leq 2\pi\sqrt{\frac{E}{C}} \tag{5}$$

For round end columns, the 2 [in equation (5)] is to be omitted.

If, for wrought iron, $E = 28{,}000{,}000\cdot00$ and $C = 60{,}000\cdot00$ equation (5) gives for flat ends:

$$\frac{l}{r} = 136 \text{ (nearly)};$$

and for round end columns:

$$\frac{l}{r} = 68 \text{ (nearly)}.$$

Hence, it follows that the *coefficients and exponents of* $\left(\frac{l}{r}\right)$, *or* $\left(\frac{r}{l}\right)$, *in equations* (1) *and* (3) *or* (4) *cannot be applied, as they stand, to fixed end wrought iron columns in which* $l \div r$ *exceeds about 140, or to round end columns in which the same ratio exceeds about 70.* Columns with other conditioned ends will fall between these limits.

These limits will exclude a very large portion of the columns used by engineers, and nearly all of those which have been experimentally treated. Below the limits indicated, and possibly far above, therefore, it can only be expected that equations (1), (3) and (4) may give *forms* to which are to be fitted empirical quantities in the shape of coefficients or exponents of $r \div l$, or of the reciprocal of that ratio.

The reason of the failure of the equation (1) below the limit indicated is to be found in the fact that the analytical process by which it is deduced is virtually based on the assumption that the lateral dimensions of the column are indefinitely small, so that whatever may be the length, the condition of applicability always exists.

Let, then, equation (1) be written in the form:

$$\frac{P}{S} = p = y\left(\frac{r}{l}\right)^x; \tag{6}$$

in which y and x are variables.

For other values (r^1 and l^1), of r and l, equation (6) becomes:

$$p^1 = y\left(\frac{r^1}{l^1}\right) \tag{7}$$

Dividing equation (7) by equation (6), then taking logarithms and solving for x:

$$x = \frac{\log.\left(\frac{p^1}{p}\right)}{\log.\left(\frac{lr^1}{rl^1}\right)} \tag{8}$$

Subtracting equation (7) from equation (6) and solving for y:

$$y = \frac{(p - p^1)}{\left(\frac{r}{l}\right)^x - \left(\frac{r^1}{l^1}\right)^x} \tag{9}$$

With a sufficient number of carefully made experiments the method of least squares could be used to advantage in the determination of x and y.

The preceding formulæ will first be applied to the results of experiments made on Phœnix columns at Watertown, Mass., and which were published last August in the *R. R. Gazette* and *Iron Age*. The column "Experimental," in table I, contains the mean results of those experiments.

Now let there be taken:

TABLE I.—PHŒNIX COLUMNS.

	Length.	$l \div r$	Experimental. Pounds.	By Eq. (10). Pounds.
Flat End Columns.	28·00 feet	112·0	34,650·00	34,550·00
	25·00 "	100·0	35,150·00	35,000·00
	22·00 "	88·0	35,000·00	35,530·00
	19·00 "	76·0	36,130·00	36,150·00
	16·00 "	64·0	36,580·00	36,900·00
	13·00 "	52·0	37,000·00	37,800·00
	10·00 "	40·0	36,440·00	39,000·00
	7·00 "	28·0	40,700·00	40,630·00
	4·00 "	16·0	50,400·00	43,400·00
	0·66 "	2·7	57,200·00	53,400·00
	25·22 "	68·8	36,000·00	36,570·00
	8·75 "	24·0	42,200·00	41,400·00

$$\frac{l}{r} = 28 \quad . \quad . \quad . \quad . \quad . \quad p = 40{,}700$$

$$\frac{l^1}{r^1} = 112 \quad . \quad . \quad . \quad . \quad . \quad p^1 = 34{,}650$$

Equations (8) and (9) then give:

$$x = 0{\cdot}117\text{; and } y = 59{,}723 \text{ pounds.}$$

Then let there be written:

$$p = 60{,}000\left(\frac{r}{l}\right)^{0.117} \tag{10}$$

The various values of $\left(\frac{l}{r}\right)$ in the table, inserted in equation (10) give the results contained in the last column.

If the experimental results be shown by a curve, it will be seen (as is, indeed, evident from the table) that that corresponding to $l \div r =$ 40·0, (36,440), is abnormally low, while that corresponding to $l \div r =$ 16·0, (50,400) is abnormally high. With these two exceptional cases omitted, the results are seen to be very satisfactory, the greatest divergence existing for the shortest columns. The constants in equation (10) might be so determined as to distribute this divergence more nearly uniformly throughout the range of $l \div r$, but it is thought to be best to place it where it is.

It is both interesting and important to observe that when $r = l$; $p =$ 60,000·00 pounds per square inch; about the ultimate compressive resistance of wrought iron.

The remaining experiments to be examined are those of Mr. Bouscaren on "Keystone and "Square" columns. The latter was a closed box column composed of two channel bars and two plates.

Proceeding in the same manner as before:

For swelled Keystone columns:

$$p = 78{,}000\left(\frac{r}{l}\right)^{\frac{1}{4}} \tag{11}$$

For straight Keystone columns:

$$p = 87{,}000\left(\frac{r}{l}\right)^{\frac{1}{4}} \tag{12}$$

For square columns:

$$p = 303{,}000\left(\frac{r}{l}\right)^{\frac{1}{2}} \tag{13}$$

Table II contains the experimental results of Mr. Bouscaren and the results of the application of equations (11), (12) and (13). The range of $l \div r$ in these experiments is utterly insufficient, and too discontinu-

TABLE II.

	Length.	$l^2 \div r^2$	Experimental. Pounds.	By Eq. (11) or (12). Pounds.		
Flat End Columns.	5·00 feet	326	33,600·00	37,800·00	Swelled.	
	15·00 "	2,991	28,800·00	28,700·00	Swelled.	
	27·00 "	9,646	24,100.00	24,800·00	Swelled.	
	15·00 "	3,130	36,900·00	28,500·00	Swelled.	Keystone.
	27·00 "	9,189	21,100·00	24,900·00	Swelled.	Keystone.
	27·00 "	9,157	25,400·00	24,900·00	Swelled.	Keystone.
	27·00 "	8,718	25,000·00	28,000·00	Straight.	Keystone.
	27·00 "	9,391	27,500·00	27,700·00	Straight.	Keystone.
	27·00 "	9,157	30,000·00	27,800·00	Straight.	Keystone.
	15·00 "	3,519	30,000·00	31,350·00	Straight.	
	15·00 "	4,136	32,000·00	30,700·00	Straight.	
	27·00 "	10,714	27,800·00	27,300·00	Straight.	
				By Eq. (13)		
	26·00 "	10,414	30,000·00	30,000·00	Square.	
	24·00 "	7,133	33,200·00	33,000·00	Square.	
	27·00 "	9,623	30,200·00	30,600·00	Square.	

ous for the establishment of a perfectly satisfactory formula; and some of the experimental results are evidently phenomenal. These experiments, however, are the best to be had and will give some idea, at least, of the value of the proposed formulæ. Bearing these considerations in mind the results by formulæ are seen to be very satisfactory.

Reviewing both tables, one cannot fail to observe that, within the limits of the experiments, the formulæ give very close results; much closer, it is believed, than those of any form of Tredgold's equation. The more inaccurate character of the latter, as deduced analytically, is thus confirmed by experiment. The larger values of y and x with increasing values of $l \div r$, as shown in equations (11), (12) and (13), afford also an empirical confirmation of the analytical process, by which Euler's formula is established, as well as the analytical limits prescribed for its applicability.

Success of the Optical Telegraph.—The optical telegraph has succeeded so well in Tunis that the insurgent Arabs are now unable to interrupt the regular correspondence between the different corps of the French army. The same system is also employed in Algiers.—*Les Mondes.* C.

THE FLANNERY BOILER-SETTING FOR THE PREVENTION OF SMOKE.

By Charles A. Ashburner, Philadelphia.

Read at a meeting of the American Institute of Mining Engineers, October, 1881.

The appliances which have been proposed, and the modifications in the construction of boiler-furnaces which have been made for the prevention of smoke, and the utilization of what are ordinarily called the waste products of combustion, have been innumerable.*

The Flannery boiler-setting, which I wish briefly to describe to the members of the Institute, contains probably no one new original device; but it is rather a new combination of parts which, in its practical working, effectually prevents smoke from being thrown off from the chimney, and utilizes the heat units contained in the products generally lost. The quantity of fuel required to produce a given result is, in consequence, reduced.

As early as 1858 one hundred and three different plans of boiler-furnaces for the prevention of smoke were submitted at one time to the Steam Coal Collieries' Association, New-Castle-upon-Tyne. In a report upon these plans made by Messrs. Longridge, Armstrong, and Richardson, the furnaces were divided into seven distinct groups, according to the principles involved in their construction. The plans which have been proposed since 1858 have been, in most cases, more practical, more economical, and more efficient applications of the same principles.

The products of the combustion of bituminous coal, on a simple furnace fire-grate, are generally considered to be steam, carbonic acid, carbonic oxide, and soot. Of these, the first two are incombustible, the last two combustible. To these four products may be added the nitrogen of the air.

In cases, even where the draft of air through the grate-bars is not excessive, there is a certain amount of unconsumed oxygen which passes through the boiler flues with the products of combustion. Abso-

* An exhibition was lately held in London "of apparatus of all kinds devised to prevent smoke."

lutely perfect combustion of bituminous coal produces only steam and carbonic acid. The more nearly a furnace approaches this result, the more efficient is it in economizing fuel and in the prevention of smoke, or, more strictly speaking, soot, which is the solid carbon contained in smoke.

The economy of combustion in the Flannery furnace lies in the fact that the soot and carbonic oxide (which pass off through the chimney of an ordinary furnace) are almost entirely converted into carbonic acid before leaving the boiler flues. It is not my purpose to claim for this furnace the greatest economy of construction or duty, or even to make comparisons with other furnaces or boiler-settings which have been devised to accomplish the same end, but merely to describe a boiler-setting which, by experience, has been found to be practical and economical, and which seems to accomplish all that the designer claims for it. It is impossible for me to state in precise terms the value of the increase of heat obtained. As a rule, practical results differ so widely from theoretical computations that they can best be made after the determination of empirical values. The most important results to be noted, where this furnace is at present being used, are: The total absence of smoke where a dirty and highly bituminous coal is being consumed, a total saving of about 33 per cent. of the coal required in au ordinary boiler-setting with the use of the same boiler and engine, and a great saving in the labor required to keep the flues clean.

The front portion of the furnace may be constructed after any of the ordinary designs which are applicable to a plain cylinder, cylinder-flue, cylinder-tubular or the other general forms of steam boilers in common use. The boiler which is illustrated by the accompanying drawings is an ordinary cylinder-tubular boiler which is being erected at Beloit, Wisconsin, for the Rock River Paper Company.

The most important points to be noted in this boiler are: The gas-flues at G (Fig. 1), where the temperature of the products is equalized; the secondary grate, A, with incandescent coals through which the products are passed, and the air-ducts, C, above this grate, where heated air is introduced, whereby combustion is completed in the chamber I.

After combustion has taken place at the front grate, X, the products resulting therefrom pass under the boiler and over the bridge-wall, M. At the rear end of what is called the combustion-flue, and a short distance (about 1 foot) back of the end of the boiler, the gases and soot

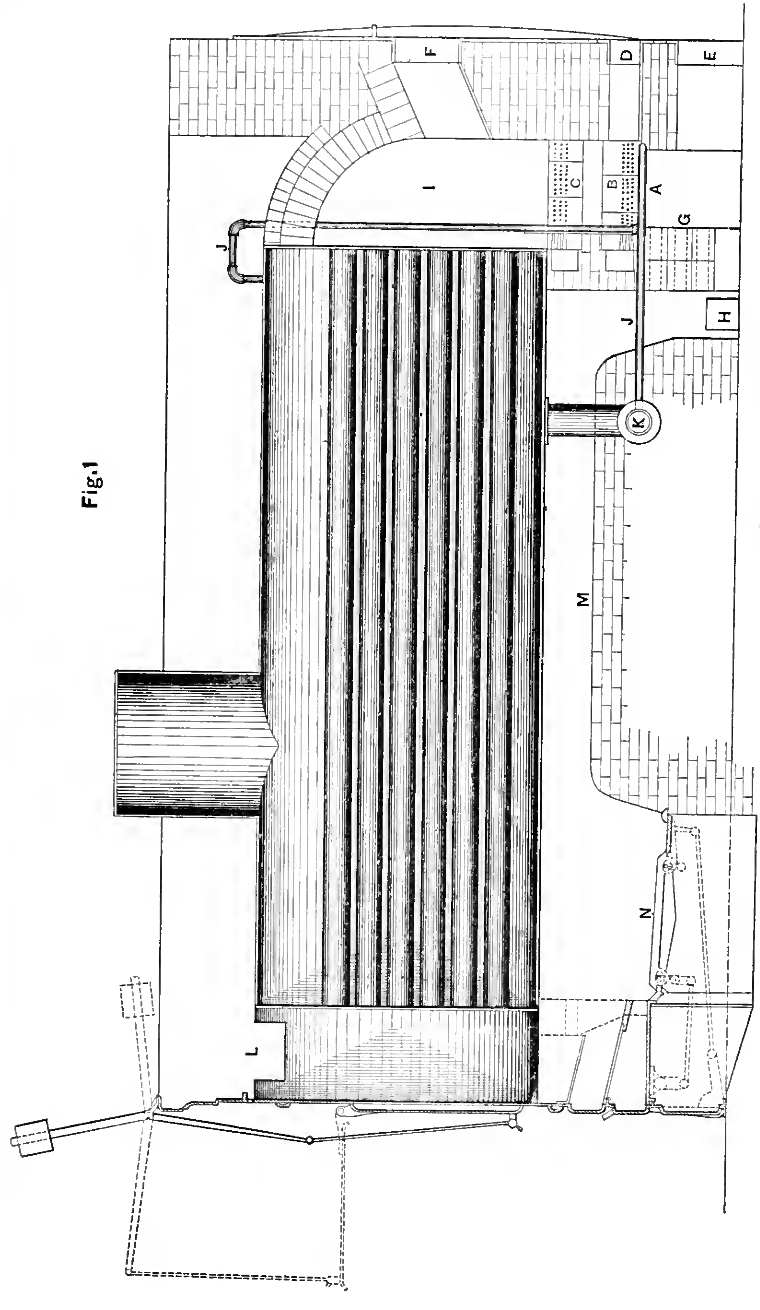


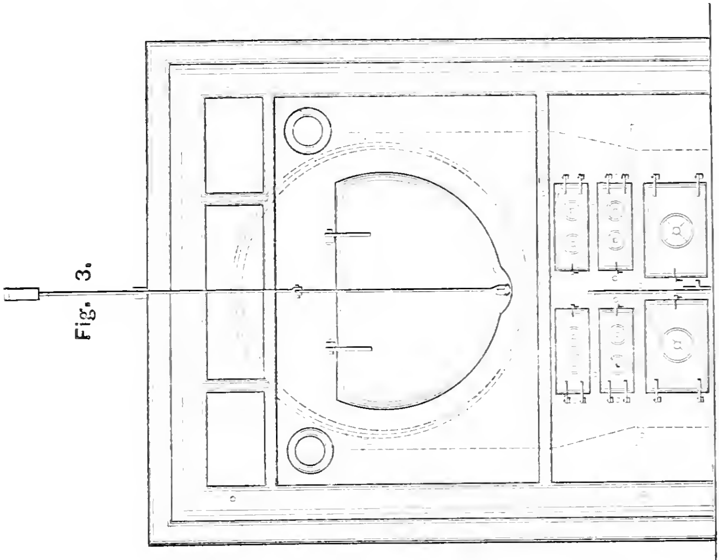
Fig. 1

LONGITUDINAL SECTION

Scale ¼ inch to 1 foot.

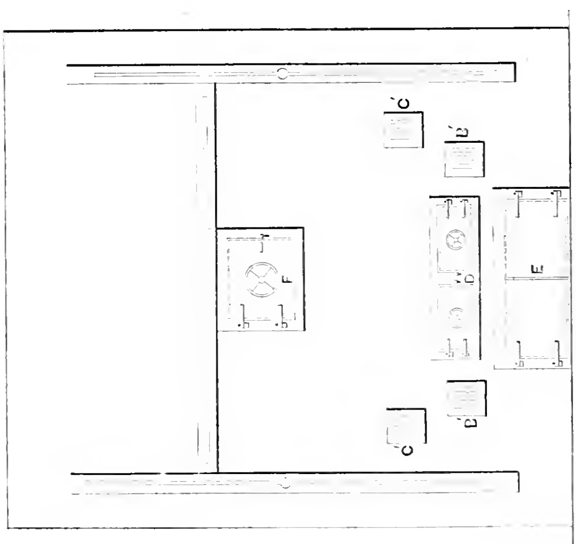
are deflected by a firebrick wall downwards and caused to pass through 25 circular flues in the lower part (Figs. 4 and 5). These flues are 3

Fig. 3.



FRONT ELEVATION

Fig.2.



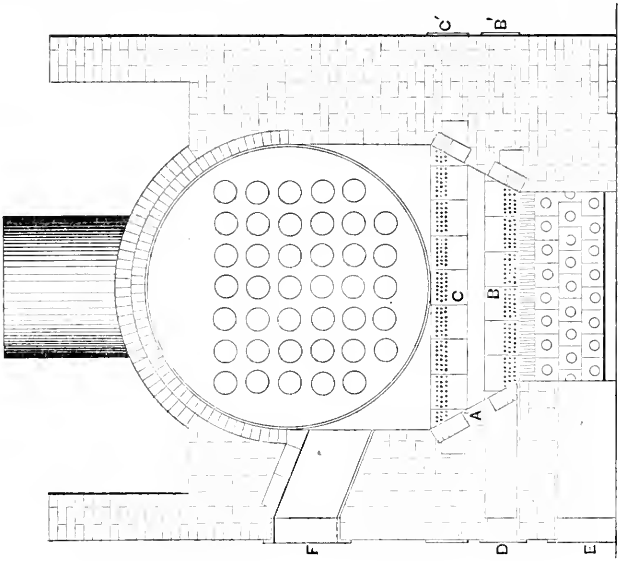
REAR ELEVATION

Scale 1/4 inch to 1 Foot

inches in diameter and 1 foot 3 inches long. In the furnace which

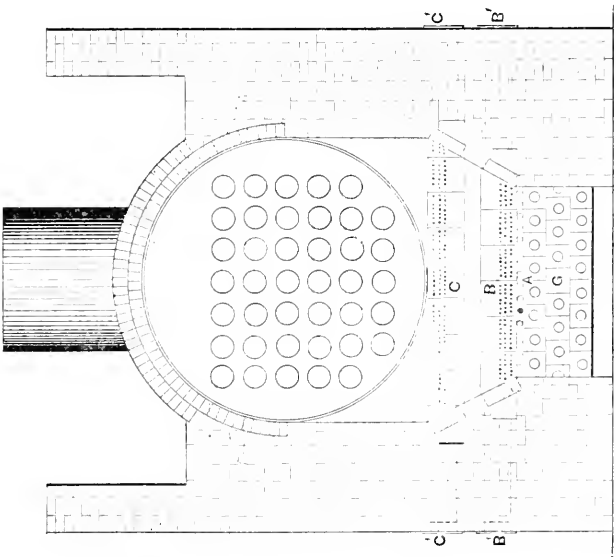
has been working for some time at Akron, Ohio, there is but one large

Fig.5.



CROSS SECTION WITH TILE GRATE
DOORS ON THE SIDE

Fig.4.



CROSS SECTION WITH WATER GRATE

opening in this wall, but the substitution of a number of smaller flues

is thought to be a decided improvement. The flues are cleaned when necessary from the ash-door, E; the ashes may be taken out from the door E or, better, from the door H, which is placed for this purpose. In practice the flues do not become coated with soot.

After going through these flues the products pass up through the water-grate, A, which is covered with incandescent coal. The fuel here may consist of wood or anthracite coal or, better still, coke. The grate is surrounded by a firebrick wall perforated by holes, B, which lead into an air-duct opening at the doors B′ (Fig. 2). This air-duct is only used in kindling or when the fire on the secondary grate becomes dead. In cases where limestone water is only to be had, a tile-grate is employed instead of a water-grate (see Fig. 5). The latter is, however, adjustable and can be readily replaced when the pipes become coated with lime or burnt. Immediately above the surface of the incandescent fuel there is a second air-duct, C, C′, which is similar to the first, and which admits of the constant influx of air. The air is heated before entering the furnace by a free circulation around the wall confining the incandescent coals. The charging door for this grate is at F; I is the combustion-chamber, from where the ultimate products pass through the boiler-flues and are carried off by the chimney located at the front end of the boiler.

The principles involved in the working of this furnace are familiar ones. When atmospheric air enters the incandescent coal on the front grate its oxygen unites with the carbon of the coal and forms carbonic oxide. The excess of air becomes heated and, if the temperature is sufficiently high, a union of the carbonic oxide with the oxygen of the air takes place and carbonic acid results. This is the case only in perfect combustion. In experience it is found that the gases above the grate and in the combustion-flue beyond the bridge-wall are carbonic oxide and air which have not united, in addition to the carbonic acid. The products of combustion which come from the front grate and enter the restoring flues, G, are, therefore, a mixture of carbonic acid, carbonic oxide, air, soot and steam.*

In substituting a number of flues for one large one, a greater surface is gained and the gases are more homogeneously heated. Of course these flues cannot give out any more heat than they absorb from the heated products as they come from the first grate. As the

* Nitrogen is not considered, as it does not directly affect combustion.

heat of these products is variable, due to firing and other causes, the heat of the flues will be an average of the heat of the products, and the gases as they enter the ash-pit of the second grate will have a more uniform heat than before entering the flues. When these products enter the incandescent coal on the second grate the carbonic acid unites with a portion of the carbon of the fuel and forms carbonic oxide. This is a direct loss of heat units.* The heat, however, is regained by the carbonic oxide thus formed uniting with the oxygen of the air introduced through the ducts C, C′, and carbonic acid results. The carbonic oxide which comes from the front grate is raised above the point of ignition by the incandescent fuel and unites with the oxygen of the introduced air and forms carbonic acid. The excess of atmospheric air enters the coals on the second grate and undergoes the same conversion as that which took place with the air entering the first grate. The particles of carbon, forming the soot from the first grate, are raised to incandescence and, uniting with the air from the ducts C′, C′, form carbonic acid.

The steam is decomposed in passing through the coals on the second grate, the oxygen uniting with the carbon forming carbonic oxide which is afterwards converted into carbonic acid above the surface of the coals. The liberated hydrogen unites with the oxygen of the air introduced through the ducts C, C′, and again forms water. The ultimate products resulting from combustion in the Flannery furnace are thus carbonic acid, steam and a small amount of carbonic oxide,† but no soot.

The gases which go off in the chimney are of a higher temperature than in an ordinary furnace-setting, and this fact very materially assists the draught. At the Akron Water-works the chimney is erected at the rear of the boiler and, although the gases are returned from the smoke-arch the entire length of the boiler, a sufficient draught has always been maintained.

A number of the Flannery furnace-settings have been constructed and, after a trial extending over several months, have produced more than anticipated results in economizing fuel, in the consumption of

* One pound of carbon in burning to carbonic acid gives out 14,500 heat units, one unit being the amount of heat required to raise one pound of water from 39° to 40° Fahrenheit. The same amount of carbon in burning to carbonic oxide gives out 4400 units.

† If the furnace is properly fired and the draft properly regulated, all the carbonic oxide should be converted into carbonic acid in the combustion-chamber, I.

soot and consequent prevention of smoke, and in a reduction in the labor, especially in that required to clean the flues.

At the Akron Water-works, recently constructed, two tubular boilers, 5 by 18 feet, with 64 4-inch flues each, have been set on the Flannery system. Two Worthington pumps have been erected, one a compound high pressure, the other a compound condensing, Up to the present time the high-pressure pump and one boiler have alone been in service. The facts which have been noted in regard to the efficiency of the furnace have been very general, but they are such as to indicate its economy. The furnace has been fired, day and night, for eleven days, with 14 tons of a dirty, bituminous slack coal, which is mined in the vicinity of Akron and sold at the works for \$1.00 per ton. On the second grate Connellsville coke has been used, costing \$6.00 per ton. For every ton of coal burned 300 pounds of coke have been used, the coke costing \$0.90 per ton of coal consumed. The total cost of fuel for eleven days was \$26.60.

The reservoir attached to the works is 210 feet above the pumps and 2700 feet distant. The consumption of water has been about 1,000,000 gallons per diem. To do the same work the boiler with the usual setting would have required at least 35 tons of coal, at a cost of \$35.00.

The average saving which would result in most cases from the use of the Flannery furnace would undoubtedly be greater than that shown at Akron, where the coal used is very poor and the cost exceptionally low. At Akron local conditions made it necessary to return the gases from the smoke-arch to the rear of the boiler where the chimney is located, through a flue 40 inches square and 27 feet long. This is considered to be a disadvantage. I am informed by the superintendent of the works that the labor required to run this boiler is one-half of that which is ordinarily required with the usual setting.

The advantages which are claimed for this boiler-setting are: Economy of fuel and prevention of smoke, economy of labor, more even action of the boiler and its longer continuance in service, due to the small amount of deposits in the flues.

The system is particularly applicable in the setting of boilers where continuous service is required, where the cost of the fuel is great, where the space occupied by fuel is valuable or where the production of smoke is objectionable.

MILK.

By Reuben Haines.

[A Lecture delivered at the Franklin Institute, February 27, 1882.]

Milk, as we all know, is one of the most important foods of man, more especially, because it constitutes usually the exclusion food of the infant during the first few months of its life, and the most important constituent of its food for a year or two afterwards. We should also consider that, from childhood all through life, it is still largely used as a very desirable constituent of a multitude of culinary preparations and as an occasional drink. Statistics gathered from London, Paris, Königsberg, and Munich show the average daily consumption of milk per head of the whole population to be $\frac{1}{2}$ pint or one tumblerful—butter, $\frac{2}{3}$ oz., cheese, $\frac{1}{3}$ oz.

The milk yielded by the whole class of mammalia or suckling animals is essentially the same in its constitution—it contains the same substances in all but in varying relative amounts.

The opinion used to be prevalent that milk in its origin was simply an exudation of the blood, and derived directly from it either by filtration through the membranes of the blood vessels, or by a selective power exerted by the mammary gland on the materials of the blood. This, however, is now considered untenable. The researches of Fürstenburg and Voit have shown that the constituents of the blood are first utilized in the formation or building up of the cells of the milk glands, in other words, the breasts of the animals—they go to form flesh. Then milk is formed from this by its decomposition or destruction through what is termed the fatty degeneration of the cells of the mammary gland, the sweat glands of the skin and the general metamorphosis of their contents. In this manner the solid constituents of milk are formed, while the water of the blood simply percolates through the tissues into the milk. Against the theory of the milk being directly derived from the blood may be instanced two facts, namely, that casein or cheese and milk sugar are not constituents of the blood, and hence must be formed by a special action of the milk glands; and secondly, the composition of milk does not vary like that of the blood according to different kinds of food digested by the animal. Milk has a tolerably

constant composition through all the changes of food of different kinds, but of similar degree of nutritiousness. Thus, for example, it has been found by G. Kühn, that the quantity and quality of cow's milk will vary according to its richness, or otherwise, in nitrogenous substances in general, but an increase of fat or oil or of sugar in the fodder has no influence upon the quantity and quality of the milk, and it is found impossible simply by alteration of food to increase one constituent of the milk over another.

In support of the more recent theory of milk formation just stated, we have the fact that the milk present, shortly before and after birth, is found by the microscope to contain cells undergoing decomposition. This is called the colostrum, and is regarded as an imperfectly formed milk. A somewhat similar milk is secreted during some acute diseases.

Dr. J. König,* of the agricultural experimental station at Münster, in Wiesbaden, from whose recent work on foods and drink I have largely drawn for this lecture, thus defines "milk as cell-structure made fluid, and every suckling animal as a carnivor which consumes the milk-gland organs formed out of the blood of the suckling mother."

The chief constituents of milk are water, casein, albumen, fat, milk-sugar and salts.

The water varies in single animals between 80 and 90 per cent., depending in one and the same species upon individuality and the maintenance of food in quantity and quality.

The group of nitrogenous substances comprise especially true casein and albumen. Both of these together, with one or two other similar substances, are classed under the collective term of casein. The coagulation of the casein produces the curdling of milk and forms the curds or cheese. The cause of the spontaneous coagulation of casein has long been a matter of dispute. Hammersten, of Upsala, has shown that the casein coagulated by acids has different properties from that coagulated by calf's rennet. He also regards that action produced by rennet to be due to a special ferment existing in the latter and capable of taking place in the complete absence of either milk-sugar or lactic acid. The phosphate of lime existing in the milk appears to have an important influence in causing the coagulation. Hammersten believes the ferment causes the casein to split up into two separate forms, one of which is insoluble in a solution containing phosphate of lime, while the other remains in solution. W. Kirchner, in a work published in

* Die menschlichen Nahrungs- und Genussmittel. Von Dr. J. König, Berlin, 1880.

Dresden, in 1877, considers Hammersten's soluble modification of casein as identical with peptone, and he thinks that the difference in digestibility noticed between human milk and cow's milk is owing to the varying proportion of peptone in any given milk. Some authorities believe the difference in digestibility to be owing to the fact that the casein of cow's milk coagulates in large flakes while that of human milk occurs in small flakes.

The casein is not in true solution, or only partly so, according to Hoppe-Seyler, etc. The fat of milk is essentially the same thing as butter. It occurs in milk in the form of minute globules to which is due the color and opacity of milk. On standing at rest for some time, these fat globules being of lighter specific gravity, rise to the surface and form the cream. The opinions of eminent authorities are divided upon the question of the exact condition in which the fat occurs in milk. Some believe the milk globules are surrounded by an envelope of casein, while others hold that no envelope of casein exists at all, but milk is a true emulsion of the fat. Soxhlet has made numerous experiments which are decidedly favorable to the latter hypothesis. The fat of milk, like butter, is composed chiefly of three fatty substances with minute amounts of some volatile fatty acids.

Milk sugar occurs in human milk and in the milk of herbivorous animals. It forms hard glittering crystals of a slightly sweetish taste, soluble in 6 parts of cold and 2½ parts of boiling water.

The ash or mineral salts of milk are chiefly phosphates and chlorides of lime, potash and soda, with a little magnesia and iron, in which the phosphates of potash and lime predominate in cow's milk. In some cases sulphates are found in natural milk.

The following is the average composition of the milk of different animals.

	No. of Analyses.	Water.	Casein.	Albumen.	Fat.	Sugar.	Salts.
Human milk,	190	87·09	0·63	1·31	3·90	6·04	0·49
Cow's "	300	87·41	3·01	0.75	3·66	4·82	0·70
Goat's "	70	86·91	2·87	1·19	4·09	4·45	0·86
Sheep's "	16	81·63	4·09	1·42	5·83	4·86	0·73
Lama "	3	86·55	3·00	0·90	3·15	5·60	0·80
Camel's "	2	86·94	3·84		2·90	5·66	0·66
Mare's "	27	90·71	1·24	0·75	1·17	5·70	0·37
Asses' "	17	90·04	0·60	1·55	1·39	6·25	0·31
Swine "	9	84·04	7·23		4·55	3·13	1·05
Dog's "	16	75·44	5·53	4·38	9·57	3·19	0·73
Cat's "	1	81·63	3·12	5·96	3·33	4·91	0·58
Elephant* "	3	67·85	3·45*		19·57	7·33*	0·65

* Average of two analyses. Casein and sugar in average of three analyses, 11·03 per ct.

Of these analyses, of course, the chief interest lies in those of human milk and cow's milk, but goat's milk is also, as we know, used as food to a considerable extent. The latter differs from cow's milk chiefly in containing much more fat, which sometimes reaches a maximum of 9 per cent. It has, however, a peculiar taste, which renders it unpleasant to many persons. Its casein coagulates in large clots. Sheep's milk is interesting as being the material from which Roquefort cheese is made. It is one of the most dissimilar from human milk, but is used for human food in montainous regions, as in the Apennines, Carpathian mountains, and also in Holland. Camel's milk and mare's milk are used by the Kirgis and Tartars to make their koumiss. Asses' milk is used in France, as a substitute for human milk for children. It approaches most nearly to human milk in composition, but less rich in fat and is more watery. Carnivorous animals, such as the dog and cat, yield milk richer in nitrogenous substances, and quality of the milk is also more influenced by the kind of food than is the case with herbivorous animals. Elephant's milk, which was obtained for the first time last year, is given as a curiosity for its enormous richness in fat, approaching to the condition of cream. It is also rich in sugar.

Inasmuch, however, as cows milk is in this country at least almost the only commercial milk, and hence, the only milk practical as a substitute for human milk, we will confine our attention to the consideration of these two kinds.

On comparing the composition of human milk and cow's milk, we find the following differences. (J. König.)

Human milk has a slightly alkaline reaction to test paper, while cow's milk has a reaction which is described as both slightly alkaline and slightly acid at the same time, and soon becomes distinctly acid.

Human milk contains more albumen in proportion to the casein. It contains more sugar and has a sweeter taste. Its fat globules are larger, about double the average size of those in cow's milk. Its casein is coagulated by the acid of the gastric juice in small finely-divided flocks, while that of the cow coagulates in larger flocks.

In regard to the mineral ingredients or ash cow's milk is poorer than human milk in chloride of potassium, but richer in phosphate of lime.

Human milk varies very greatly in its richness in fat. In 190 analyses the fat varied from 1·71 to 7·60 per cent. In some cases the fat is less than 0·50 per cent., especially after a long fast as just before breakfast. The general richness of milk is dependent upon the

richness of the food, but the variations from this cause occur more in the fat and sugar than in the nitrogenous substance.

The percentage of ash is subject to great fluctuation, probably partly owing to the particular kinds of food, for a slight increase of chlorine and sodium is noticed when common salt was added to the food. Nevertheless, there can be no doubt, from actual analysis, that human milk is subject to greater fluctuations in composition than in the case of animals. It is also well known that the emotions, such as fear, anger, grief, etc., affect both the quantity and quality of human milk, as is shown by actual experience.

In an analogous manner but in a less degree the composition of cow's milk varies according to different circumstances.* Among them may be named the age of the cow; its race or breed; the number of previous calvings; time from last calving; time of day when milked; whether stall-fed or at pasture; if stall-fed, the kind and quantity of fodder; whether the sample was from the first part of the milking of any one cow or from the last part of the same, or in other words, from the "fore milk" or the "strippings," or, whether the sample was taken from the whole of one milking of any one cow previously thoroughly mixed; the general condition of health of the cow; cleanliness, warmth and ventilation of stable. In addition to these there appears to be what the Germans call individuality or idiosyncracy, by reason of which cows of the same breed have different individual peculiarities of milk even when under the same conditions in other respects. This peculiarity is analogous to the quality observable in men who remain lean and thin, or become corpulent, independent of the kind and quantity of food, and even when efforts are made to produce a contrary result. In man, however, as we know, such peculiarities are often inherited and are then of the nature of race characteristics.

The influence of race upon quality of the milk is shown by the following analyses by O. C. Wiggin, of Providence, R. I. (Johnson's Encyclopædia, art. Milk by C. F. Chandler.)

	Water.	Solids.	Fat.	Casein.	Sugar.	Salts.	Sp. Gr.
1. Alderney,	83·04	16·96	8·07	5·02	3·05	79	1·030
2. Alderney,	83·93	16·07	8·28	3·14	4·02	63	1·029
3. Durham,	84·56	15·44	6·41	4·35	3·97	68	1·033
4. Ayrshire,	86·60	13·40	3·70	4·76	4·35	59	1·031
5. Devon,	84·71	14·29	3·96	5·29	4·23	81	1·033

* Gorup-Besanez — "Physiologische Chemie;" J. König — "Nahrungs- und Genussmittel."

The first was made in January, all the rest in June. These I suppose to be single analyses, not averages.

An analysis of my own of the mixed milk of two Alderney cows (part Durham) made in December.

Water.	Solids.	Fat.	Solids not Fat. Casein, Sugar and Ash	Ash.	Sp. Gr.
84.17	15·83	5·53	10·30	·68	1·0321

The sample was taken at a time when the milk was much less rich than it had been during the summer months.

In regard to the time elapsed from calving it has been found that with the continuance of the same food, after some time the dry solids and nitrogenous substances, viz., casein, will gradually increase and the fat and sugar decrease. By giving a richer nitrogenous food this falling off in fat and sugar will be delayed for a much longer period.

Evening milk is generally richer in fat than the morning milk, while the other constituents remain about the same, as shown by the average of analyses conducted for a whole year by a number of chemists. Baumhauer did not find this the case at all constantly, however, in his analyses.

The milk first drawn from the udder will very frequently be very deficient in fat, in some cases almost entirely wanting in it,* while the last which is drawn is very much richer in fat than the average. The other constituents remain nearly the same. Hence, it is very important to mix all the milk of one milking before it is served to customers or an analysis made of it; otherwise, some get poor milk and others rich milk from the same cow. Two cases are on record in which milkmen tried to throw discredit on a chemist's analysis by sending him samples from the first quart of the milking.

From all that has been said, we will perceive that cow's milk has naturally quite a variable composition. It is this fact that has been one of the chief obstacles in the detection of adulteration in the commercial article. That milk is subject to considerable adulteration is a notorious fact. The kind of adulteration practiced is usually that of watering the milk, and of robbing it of the cream by skimming. The mixing of foreign substances with the milk has occasionally been detected, but is probably of seldom occurrence. The methods of watering and skimming being, however, so easily practiced at the dairy,

* *Vide* A. W. Blyth—"Foods and Poisons," London and New York, 1879.

and the necessity of employing milk agents for city supply render the temptations to it very great.

Every family ought to be able to obtain pure and wholesome milk, more especially on account of its forming the chief part of the food of young children. Yet many people in large cities find it impossible to obtain milk in a satisfactory condition, and many more are ignorant of the poor quality of the milk served them. From one point of view the real importance of the question turns upon the concealment of the impoverishment of the milk, and the palming off of a poor article of food for a good one, constituting a fraudulent depreciation of the value of one of the necessaries of life. Those who know its real value can provide accordingly. They will take more of it, if it is poor or make up the deficiency with other food. If they pay the usual price of good milk they do not get the full value of their money, bus the fault in that case is, partly at least, their own, for they purchate knowingly a poor article at a high price. But a mother who is ignorant of the fact that half of the nutritive substance of the milk has been abstracted may be starving her child without knowing it. It may become sick and wasted, yet she may not know that this is the cause. It is well known to medical men that one of the chief dangers to children under one year of age, among the poor in large cities, is death from *want* of sufficient nourishment. Yet the poor will be tempted to buy the poor article knowingly, but are ignorant of the disastrous consequences.

Now in what way can we most readily and accurately know the true condition of any milk? By what means can we detect adulteration in such a manner as to convict the offender? Upon this point, unfortunately, there is much difference of opinion, and owing to these differences the guilty party frequently escapes, even from the court-room. Many cases, also, of minor degrees of adulteration, are never brought to trial, because of the great uncertainty of obtaining conviction. One of the chief of these difficulties lies in the uncertainty existing as regards an absolutely fixed standard for pure unsophisticated milk. We have but to consult the records of very numerous analyses published in manuals on this subject to find such wide variations as apparently to put such a standard out of the question. Many hundreds of such analyses have been made and an average composition has been calculated from them, and this is proposed by many as the proper standard; but as many cases of pure milk will necessarily fall below this average,

others contend that the standard by which to establish adulteration must be low enough to include the poorer grades of natural milk as pure, so that injustice shall not be done to innocent dairymen who may happen to have cows of poor stock. But placing the standard so low will thus enable unscrupulous milk-men to water a rich quality of milk to the extent of ten or twenty per cent. without risk of legal penalty.

Differences in the richness or in other words the composition of the milk, which I have brought to your notice, have their influence upon its specific gravity or its weight as compared with that of distilled water. Statements have been published that the specific gravity of pure milk from single cows may vary all the way between the limits of 1·016 and 1·040, but it usually does not vary more than from 1·027 to 1·034, while skimmed milk has a specific gravity of 1·035 to 1·038. Average good milk mixed with half its bulk of water has, on the other hand, a specific gravity of 1·016. Inasmuch, then, as the specific gravity is the test which is often chiefly relied upon and placed in evidence in law suits, the importance of this variability becomes very obvious.

The real source of this perplexity is probably to be found, however, in the confounding of the composition of the milk from single cows with that of the mixed milk from large herds. A knowledge of the former is necessary to arrive at facts in physiological science, but the latter is the only one with which the milk inspector has to concern himself in most cases, especially in commercial or market milk. This view has lately been advanced in forcible language by Oscar Dietzsch, analyst in the canton of Zurich, Switzerland, and author of a recently published manual on adulteration of food.* He states, that if care is taken to select unadulterated mixed milk from large herds, the variations in specific gravity and composition will almost wholly disappear. The differences above and below the average will, in fact, neutralize each other to a great extent, and the specific gravity will vary only between 1·029 and 1·031. Mr. Dietzsch also states that if great care is taken to preserve the cows in a normal state of health this variation will be still less, standing at 1·030 to 1·031.

From these facts he declares, substantially, that all milk from large herds or such mixed milk as is usually sold in cities, which has a specific gravity, either above or below these figures, viz., 1·029 and

* Die wichtigsten Nahrungsmittel und Getränke und deren Verfälschungen. Von Oscar Dietzsch. Zurich, 1879.

1·031, has been adulterated, or manipulated so as to be practically the same as adulterated. This conclusion being granted as correct, the testing of milk would seem at first sight to be an easy task, being done by men by plunging a suitable hydrometer into the milk and noting the mark to which it sinks. This would be a correct method if all the solid constituents influenced the specific gravity in the same way. In reality, while most of these tend to increase the specific gravity, the fat, which forms the most important part of the cream, tends to lessen it, or to make the milk lighter in weight. Hence arises an important complication, for if you by any means lessen the proportion of the other solids the hydrometer sinks, but on lessening the fat the hydrometer rises, and consequently by lessening both the fat and the other solids in the proper proportion, you can make the hydrometer stand at the same mark which it did in the original pure milk. The easiest way to lessen the proportion of total solids, which are heavier than water, is to add water to the milk and this will bring down the specific gravity nearer to the mark for pure water, but the fat being itself lighter than water tends to keep the specific gravity down, and consequently, if a considerable part of it be removed, the specific gravity will again aise in proportion as more fat is removed from the milk. This is practically what very many milk-men do, for it is a common circumstance for the milk-man to remove a part of the cream, either by skimming off the cream or by setting aside for milk the first part of the milking of each cow, which is poor, and putting in other pans the strippings, which he sells separately at a higher price and thus secures a double profit on his milk; but by doing this he abstracts a part of that which makes the milk lighter and leaves the milk with a higher specific gravity than should be the case with pure fresh milk. This is readily detected by the hydrometer. The knowing milk-man, however, now adds sufficient water to the milk to bring down the specific gravity to the normal point for the pure unadulterated article. He has now doctored the milk in two ways, both of which yield him a profit, and yet the hydrometer or lactometer, as it is called, will not, when used alone, indicate any adulteration whatever. It is true that the milk will be apt to look thin and poor, unless it was originally quite rich, and hence, a practiced eye might readily suspect it; but it is well known that persons unaccustomed to first-rate milk would take it without any complaint.

It is, however, possible for the milkman to avoid detection by

ordinary customers by adding some substance which will thicken the skimmed and watered milk and give it the proper color. Carbonate of soda, starch and sugar, and various coloring substances are said to have been sometimes used for this purpose. According to Baumhauer, it was customary in Holland, some years ago to use the yellowish dirty water of the canals for mixing with the milk, and at the same time give it a creamy color. The usual way in which the milk is skimmed is by taking off all the cream at night and adding the skimmed milk to the fresh morning's milk. It is thus half skim, and is composed of old and new milk mixed. Such milk is very difficult to keep in warm weather, often becoming sour almost as soon as delivered, and is therefore injurious to very young children and particularly to infants.

Another instrument which is largely used for testing milk is the cremometer, consisting of a simple graduated cylinder glass or tube, into which the milk is poured, and after a suitable time the amount of cream which has risen to the surface is measured. Although of some practical use in estimating the value of a cow for butter-making, there are many serious objections to its use in ascertaining the purity of market milk. Unless used with the most scrupulous scientific care, and also even then, it will give uncertain and varying results, so as frequently to be very misleading. The same milk will yield different amounts of cream in the same fixed time, after having been subjected to different degrees of shaking or agitation before being poured into the cremometer, the extent of variation being from six to ten per cent. Therefore, the same milk will be apt to yield different amounts of cream at the market and at the dairy. The temperature to which it has been exposed while standing in the cremometer has considerable effect on the amount of cream. Different milks containing the same amount of fat require different lengths of time to yield approximatively the same amount of cream. This is owing to the fact that some milk contains a greater proportion of large fat globules, which rise more quickly than the smaller ones. The milk of the same cow gave by the cremometer 9 per cent. of cream in the morning, and 12 per cent. in the evening of the same day, while the variation of the fat was found by analysis to be only one-tenth of one per cent. The milk of two different cows gave each 10 per cent. of cream by the cremometer, while the fat contained in one of them was found by analysis on the same day to be one-third greater than in the other. In each case great care was taken in regard to handling the milk, and the

cows were placed under the same conditions. These facts have been clearly set forth by Baumhauer, in a paper on this subject, *American Chemist*, November, 1876. To this we may add the fact that cream itself is of greatly varying composition, a rich cream containing often three times as much fat as a poor quality of cream, and hence the volume it will occupy in the cremometer will vary also. It is well known that the skim milk of a rich quality of milk, such as that of Alderney cows, is of poorer quality than ordinary skim-milk (so far as the fat is concerned), because a much larger proportion of the fat is in large globules, all of which with considerable part of the smaller globules rise to the surface and form the cream.

In fact without going into further details the volume of cream yielded by a milk in a given time is by no means an accurate measure of its richness. If the cremometer does not give trustworthy results by itself, it is surely of little use in combination with the lactometer, although this is recommended by some authorities.

Other instruments have been devised for finding the amount of fat in the milk by the eye and judging the purity thereby, but they are all open to serious objections. That which is most highly recommended is the lacto-butyrometer of Marchand and Salleron. I shall not describe it here but will state that Marchand himself admits that when it gives negative results, inspectors "should take care to have the suspected sample examined by an expert chemist. This is a measure of prudence from which they should never depart."* He thus confesses the insufficiency of his process, and it is still to be discovered whether it has any advantages over the ordinary lactometer.

In regard to the lactometer again, other circumstances besides adulteration may lead to false conclusions, especially when the mixed milk of only a few cows is examined. Ordinarily we expect a milk rich in cream to have a low specific gravity, but the casein and sugar may also be so largely increased as to counterbalance the effect of the fat, and then notwithstanding its large amount of cream it may have a specific gravity closely approaching that of skimmed milk. The eye, however, will at once perceive the difference, and an inspector with his eyes shut does not know his business.

Theoretically, the only reliable test is a chemical analysis of the milk, but there are several practical objections to its use on a large scale. For such a work a trained chemist is necessary, considerable

* H. A. Mott—"Adulteration of Milk," 1878.

length of time is required for each analysis, and the expense is, therefore, heavy. Although a large number of samples may be analyzed, at the same time none of them can be completed in less than five or six hours. It is, therefore, impossible to test milk by this means just at the time and place where reliable testing is the most needed—at the dairy or milk depot before the milk is allowed to go out to customers.

Yet we may dispose of this last objection, partially at least, if we allow the milk from which samples have been taken for analysis to pass unchallenged until the following day and so also on each succeeding day. Of course, if milk is adulterated with anything injurious, we run the risk of its doing some harm. But the chances of this occurring on any one day are so exceedingly small, even if we take into account the liability of watered milk containing "germs" of disease from polluted water, that this objection may be entirely ignored. The question of expense is a much more serious obstacle, yet this also may be lessened very materially by thoroughly systematic arrangements of the laboratory, conditioned, of course, on regularity and constancy of work to be done.

One method of avoiding the chances of failure of the lactometer to indicate adulteration is a cursory examination of each sample of milk under the microscope, and an approximate estimation of the number and size of the fat globules in the field of view at one time. The instrument need not be expensive, and a little practice would enable any one to become expert at such examination.

As has been stated the adulteration of milk consists almost exclusively in the addition of water and the partial removal of the cream. The former is clearly adulteration in the ordinary use of the word, but the latter is also now technically strictly an adulteration, for that term now legally includes the abstraction of any valuable constituent of food.

The watering of milk is not only a fraud, but is really a practice which has several times proved very dangerous to health. For the farm yard is, as a rule, not over clean, and the dairyman in total ignorance of some very important sanitary rules, often places his pump in very close proximity to the common privy or dung-heap, or takes the water for dairy purposes from a brook which is polluted directly with sewage. A number of epidemics of typhoid fever in England, which have been traced directly to the milk supplied from certain farms where typhoid fever was found to exist, give ample and convincing proof of this danger.

These epidemics of typhoid fever in England, in which the evidence of the cause being polluted milk was very strong, were as follows: The epidemic at Islington recorded in 1870; Penrith, in 1870; at Mosely, near Birmingham; at Leeds, in 1873; at Armley, near Leeds, in 1872; at Glasgow, in 1873.

Scarlet fever may also be communicated through milk. This occurs not by any adulteration, but carelessness in allowing persons having the symptoms of an eruptive disease to milk the cows, and scabs from the skin of such persons get into the milk and remain there as an active poison. Unquestionable cases of this kind have occurred recorded by Prof. Bell, of St. Andrews, and Dr. Taylor, of Penrith. An outbreak at South Kensington, London, was traced to cream.

While such dangers as these, which affect older children and adults, are of sufficient importance for our careful consideration, the chief importance of this whole subject of milk and its adulterations lies in the fact that cow's milk is the peculiar and often predominating food of very young children, and this importance comes out still more forcibly, in view of the fact of the great mortality among children under five years of age, in all large cities, and the still greater mortality among infants of less than one year old. It is very true that a large part of the mortality of infants is due to intense summer heat at a period of life when the sweat glands of the skin have not yet developed their proper functions so as to lower the temperature of the surface of the body by the perspiration and also the want of movement in the air and the crowding together in small rooms. But it is also true that improper and insufficient food causes the death of very large numbers of infants of the poorer classes.*

By the watering and skimming of the milk, not only is its nutritive value materially reduced, but the skimmed milk of one day is added to the fresh milk of the next, and the consequence is that the milk is soured, or in other ways rendered entirely unfit for children's food, even before it is delivered to the house. Diarrhœa or summer complaint, convulsions, and death may often follow as the result of such a condition of their exclusive food when they are debilitated by summer heat. It is on this account that this practice is so reprehensible, and it is this which makes rigid inspection necessary, and severe legal punishment upon all offenders justifiable. Of all the adulterations of food so often alluded to, this is one of the most flagrant and injurious to the community at large.

* *Vide* Essays by Drs. Jacobi, Meigs, S. C. Busey and J. Lewis Smith, published by the trustees of the Thomas Wilson Sanitarium of Baltimore.

THE FIRE UNDERWRITERS' REGULATIONS RESPECTING THE USE OF THE ELECTRIC LIGHT.

The electric light has made its way into such general use by reason of its great superiority in quality over every other known system of artificial illumination, that it is rapidly coming to be looked upon as a necessity rather than a luxury, in which latter category it has been customary until lately to class it. Within the past few years, however, much has been accomplished in improving the brilliancy and steadiness of the electric light, in lessening the cost of the several systems, and in perfecting their details of construction and operation; in consequence of which the electric method of illumination to-day, in one form or another, has been very extensively adopted both here and in Europe for the lighting of the streets and avenues of cities, public buildings, mills, factories, stores and the like.

But, though the superiority of the electric light in point of purity over other sources of artificial illumination is incontestible, and though the practical objection of greater cost urged against it has been largely overcome by reason of the improvements above referred to, the fact, which the occurrence of serious accidents has made very apparent, that its use was attended with danger, has given rise to a feeling of general uneasiness and distrust. The fact, which speedily came to light, that the experts of the electric lighting companies, electricians, and others claiming to be familiar with the subject, differed among themselves as to the magnitude of these dangers and the proper precautions to be taken to avoid them, was a discovery calculated rather to increase than to allay public disquietude.

The importance of the subject was such that several prominent scientific and technical organizations, among which may be named the Franklin Institute, were induced to investigate it. These investigations have contributed greatly to a proper understanding of the subject. The report of the special committee of the Institute, which examined the subject, was published in the December number of the JOURNAL for 1881, has been widely read and commented on as an admirable and authoritative statement of the sources of danger in electric lighting, and as a guide in the adoption of preventive measures to provide against them.

The New York Board of Fire Underwriters has likewise taken a strong interest in the question, and through a special committee, appointed for the purpose, they have adopted a set of regulations to govern the introduction and use of electric lights. From the nature of this organization it was to be expected that they would consider the subject from a strictly business standpoint, as their interest in it is based on purely monetary considerations. An examination of the regulations adopted as a standard by the Board confirms this view. They enter into the most elaborate details respecting the precautions to be taken to guard against danger, including therein the questions of the capacity of conductors, the proper methods of insulation, the protection of the lights, etc. In this respect the regulations established by the New York Board of Fire Underwriters will be found useful in connection with the report of the Committee of the Franklin Institute above alluded to. The regulations of the Underwriters, embracing the latest revisions as adopted at a meeting held January 12, 1882, are as follows: W.

Capacity of Conductors.

For Arc Lights—The conductor must have a weight per running foot at least equal to that of the wire (or parallel group of wires) constituting the main circuit of the magnetic regulator of the electric lamps, or of the armature of the machine employed, whichever of these is the largest.

For Incandescent Lights.—Wherever a connection is made between a larger and a smaller conductor at the entrance to or within a building, some approved automatic device must be introduced in the circuit of the smaller conductor, whereby it shall be interrupted whenever the current passing through it is in excess of its safe carrying capacity.

The safe carrying capacity of a wire is that current which it will convey without becoming painfully warm when grasped in the closed hand.

Insulation.

All wires, machines and lamps to be so mounted and secured as to insure complete and continuous insulation, with the exception of those parts (such as portions of the lamps or machines for example) where insulation is impossible, and in this case accidental contact with exterior objects must be prevented by appropriate screens or the like.

In no case must "ground circuits" be employed, or any portion of

the system be allowed to come into conducting connection with the earth through water or gas pipes or otherwise.

Exposed wires must be covered with at least two coatings, one of insulating material next the wire, of a thickness and material approved by the Board, and another outside of this, of a material calculated to protect the former from abrasion or other mechanical injury.

Where there is a possible exposure to water the first or second coating must be impervious to that fluid.

Wherever electricity is carried into a building by conductors from an exterior source a "cut out" must be provided at a point as near as possible to the entrance to such building.

The outgoing and returning wires for Arc Lights should enter and leave each building at points at least one foot from each other.

The wires passing through the exterior walls of a building should be firmly incased in substantial tubes of non-conducting material, not liable to absorb moisture, and placed in such a manner as to prevent rain water from entering the building along the wire.

In running along walls and the like wires should be rigidly attached to the same by non-conducting fastenings (the wires themselves being well insulated) and should not be hung from projecting insulators in loose loops.

All wires should be placed at a distance of eight inches for Arc Lights and two and one-half inches for Incandescent Lights from each other, and wherever they approach any other wire or conducting body capable of furnishing another circuit or ground connection they must be rigidly secured and separated from the same by some continuous solid non-conductor, such as dry wood, of at least one-half inch in thickness.

Wherever wires are carried through walls, floors or partitions in buildings, they must be surrounded by a special insulating tube of substantial material.

All joints in wires must be made in such a manner as to secure a perfect and durable contact. Continuous wires (without joints) to be used as far as possible.

Globes.

Arc Lights must be protected by glass globes, enclosed at the bottom to prevent the fall of ignited particles, and where inflammable materials are present below the lamps, a wire netting must be added

to keep the parts of the globe in place in case of its fracture during use.

All broken and cracked globes to be at once replaced by perfect globes.

In show windows and other places where inflammable materials are near the lights, spark arresters shall be placed at the top of the globes.

Automatic Shunt.

Wherever a current of such high electro-motive force is employed that if concentrated on one lamp of the series it would produce an arc capable of destroying or fusing parts of such lamp, an automatic switch must be introduced in each lamp by which it will be thrown out of circuit before the arc approaches any such dangerous extent.

Companies furnishing electricity from central stations must enter into an agreement with the New York Board of Fire Underwriters, binding themselves to test their lines for ground connections at least *once* every day (and preferable three times per day), and to report the result of such tests to the Board weekly.

Means by which those in charge of the dynamo-electric machines will be warned of any excessive flow of current, or means whereby the same will be automatically checked, must in all cases be provided.

ON THE FILTRATION OF WATER FOR INDUSTRIAL PURPOSES.

By P. Barnes, Springfield, Illinois.

Read at the Meeting of the American Institute of Mining Engineers, May, 1881.

The complete and accurate filtration of water (if the word accurate may be thus used) for the feeding of boilers, and for many similar industrial purposes, although somewhat practiced both at home and abroad, has been by no means common. Even if the exact line cannot be defined at which filtration begins to be called for, and will be found profitable, it is certain that in a large number of cases it may be employed with real advantage in the economy of fuel, and also in the greater durability of the boiler or other form of apparatus in connection with which the water may be used. It may be carried on without any attendant disadvantage of costly apparatus, or of

complex fixtures of any kind, which are liable to get out of repair, perhaps at the time, of all others, when their service is most urgently needed.

No special form of apparatus need be mentioned in this paper, nor need there be any reference to other kinds or types of fixtures than the time-honored device of an open sand-filled tank or basin. A brief discussion of these familiar details may serve to set forth the principles involved, and the entire practicability of applying them to the water-supply of nearly all kinds of industrial work. The general character of this discussion is the more desirable because the waters of different localities vary so widely, and so also do the materials which, being found near at hand, can alone be used profitably in the filtering apparatus.

It is too often supposed that a filter of any kind is, and must necessarily be, only a hopeless annoyance and perplexity to the workmen who have charge of it; but this comes chiefly from using, or attempting to use, a filter far too small for the work, or else from some error in arrangement that ought to be discovered and corrected. Sometimes the effort is made to combine the work of filtration with that of heating the water, if it be used for boilers, or possibly with the storage of the water in some tank of trifling capacity. In many cases the filter is set in some inclosed space, as an engine or boiler-room, where the interruption of cleaning becomes a genuine annoyance to all concerned.

If a simple mechanical sifting alone be attempted, and in most cases this is all that can be brought within the limit of admissible cost, then the problem becomes really a very elementary one, and need not involve any more than the plainest forms of apparatus, and the simplest kind of manipulation for the securing of useful and very perfect results. These plain and even rude appliances are in fact the ones which alone can endure the inevitable rough handling and all the usual exigencies of this class of work.

This discussion should include:

1. A description of the basin, or inclosure, for holding the filtering medium, and, if needful, for the storage of the water after the filtration.

2. A note of the method of putting in the materials used for the filter-bed, as adapted to the wide variety from which selection may have to be made, and also to the ordinary character of the water to be treated.

3. An explanation of the simple method of working under ordinary circumstances.

4. A description of the method to be employed in cleaning the filter, this being almost the sole working cost of the operation, for the first cost of construction may be kept within so moderate a limit that the interest charge upon it will be trifling.

1. The filter-basin or tank should be divided at least into two parts, so that one may be at all times ready for service. If the water is likely sometimes to be heavily charged with mud, a larger number of compartments become needful, for the time needed for cleaning is thus increased, and it is then all the more desirable that the apparatus in which the water is to be used shall be always definitely protected from injury by the mud brought in from the source of supply. These compartments should be of ample size, for the filtering process to be perfect must be carried on slowly. The mechanical sifting out of the fine impurities can only be done by passing the water through a fine-grained or dense medium, and hence the movement of the water through this medium must necessarily be slow. If space can be found, very large basins are desirable, although useful results are obtained in tanks of quite limited size. The outline may suit the space which can be devoted to the basin or tank, being either rectangular or circular as may be needful.

The choice of location for the filter-bed may be made to suit the exigencies of any given case. The basins may be put at the source of supply, perhaps at a distance from the works, the clean water alone being brought through the pipes. On some rivers the material of the bank itself is found to be an admirable filtering medium, so that the cutting or sinking of a plain trench in this material fills the whole requirement. Some filter "galleries," on an extended scale, have been thus made with excellent results. In some cases wells have been sunk by the side of a canal, and from them very pure water has been drawn in ample quantity, which, if taken direct from the muddy canal, would have been subject to a water tax, as well as wholly unfit for the required purpose.

If an open basin be employed, a screen should be so placed as to intercept leaves and similar material, so that they may not be widely scattered and more troublesome to remove. The inlet-pipe should be led in above the usual water-level, so that the amount, and character, as to cleanliness, of the supply may be constantly observed. The outlet

is necessarily led away at the bottom of the tank, and it should have, at the nearest practicable point to the filter, an open discharge, from one pipe into another or into a storage reservoir, so that the purity and the amount of flow may be approximately noted at a glance. The volume of water passing the filter will obviously diminish as the sand surface becomes saturated or filled with mud or silt, and thus, by the flow from an open outlet, the comparative condition of the filter may at once be noted.

2. The material and method of filling must be suited to the water which is passing. One grade of fineness of the surface may be quite sufficient at one season of the year and doubtful or imperfect at another. At the bottom of the basin a layer of tiles, or coarsely broken rock, should be laid, so that an ample and uniform outlet may be had for the water from all parts of the surface area. This tile bottom may serve also a useful purpose in the storage-room, which it furnishes for the clean water.

For the next layer coarsely broken brick, ore, slag, or coke should be used, or, indeed, any material which will not become softened by soaking in the water, and which is of a rather rough or angular texture in its fracture. The next layers may be of the same material more finely crushed, so that at length, at the upper surface, the whole shall be nearly or quite like a fine sand, such as will pass a forty or sixty mesh screen. This method of filling affords in the best possible way the opportunity of correcting any imperfect working, for, by changing from one filter-bed to the alternate, the first may be repacked, or a finer material may be put on as needed, until the required result is reached.

At any iron works one of the best of all materials is usually to be found, viz., hard coke, which, when crushed fine, resembles very closely the animal charcoal so universally employed for the finest filtering, either for household service or for the higher class of manufacturing. In few words, almost anything can be made to serve as filtering material which can be crushed fine enough to act as a mechanical barrier to the sediment or mud borne by the water, and there are very few works or regions in which some kind of rock cannot be obtained.

3. In the working of the filter, the uniform downward soaking away of the water alone needs to be provided for. For this purpose the water should be as uniformly distributed as possible, and should

be led on to the filter very quietly. To prevent any disturbance of the fine sand surface, a quantity of coarser rock or sand should be spread to break the fall or flow of the entering water, or a simple timber or plank apron may be laid. This method of filtration is obviously suited to the cleansing of any quantity of water, whether small or large, up to the maximum capacity of the filter. The smallest quantity is as perfectly dealt with as the largest, and the whole apparatus need suffer no material injury from any probable standing for a time unused.

In some climates an open-basin filter would be subject to freezing, and thus to a complete stopping. As soon, however, as the area or number of basins required for any given establishment has been determined, a simple shed or inclosing roof can be erected at no great cost, which, with the constant flow of the water, will be found ample to prevent obstruction from freezing. In extreme cases the tanks or basins must be fully inclosed in frost-proof casings, or placed inside of some permanent building which shall afford the needful protection.

No method of dealing with the waste water from a manufacturing establishment is so effective as filtration, so far as freeing it from impurities held in suspension is concerned. When elements held in solution must be removed or neutralized, the problem becomes a difficult one, and its solution, in the large majority of cases, quite passes the limit of admissible cost.

4. The gradual diminution of the outward flow from the filter-bed, at the open discharge pipe referred to, gives all needed warning of the choking or filling up of the surface of the sand stratum at the top. When this has reached the fixed limit, the flow of water is turned into one of the duplicate basins, and the first is suffered to become empty and to dry away for cleaning. As a rule, the mud and other obstructing sediment will not be found to penetrate deeply, and hence the removal, by scraping or shoveling, of a thin layer from the surface, of from one to three inches, will be found to restore quite fully the flow of water when it is again turned through the filter. Care must be taken in this shoveling or scraping that none of the silt material is rammed or "puddled" into the crevices of the sand which remains, for few things of its kind are more impervious to still water than a stratum of "puddled" clay or similar material. If time enough be taken to let the water soak away quite completely from the filling, then the saturated surface can be very readily shoveled off and

removed. More of the surface material can then be spread, or the water turned on at once, in case the top layer was made thick enough to permit several cleansings without removal or replenishing. The sand may be washed and returned if it be at all in scanty supply; but if crushed coke be used, its rough surfaces will eventually become so charged or coated with mud as to render it unfit for use.

It has been remarked that the cost of this cleaning is really the sole working expense attending the use of this class of filtering apparatus, and this cost need not be great, or indeed more than quite trifling. The filter must be of the primitive type thus described in order that the common labor, which alone can be charged with the detail of such things, shall make no mistake in the refilling or the cleaning required.

An important though indirect advantage attending the use of a filter, which has no connection with the work of heating the water treated in it, is that the laying off for cleaning may be done at any time, provided only that a separate compartment is so arranged that the flow may be turned through it without any delay. It is obvious enough that duplicate filter-heaters may be provided, but as a rule they are not, and hence the needed cleaning of the filter compartment must be done when the heater can be spared or is idle, as on a Sunday. This necessity is liable to lead to the running of the filter longer than it should be run, and to a general haste and imperfect cleaning when finally it is attempted. This ends at length, or is very likely to, in an imperfect working of the whole apparatus, and a complete abandonment of the attempt to filter the water at all. If, on the other hand, ample filtering appliances are provided, of the elementary type described, then the barrier thus erected for the protection of the higher classes of apparatus, from sand and débris of all kinds, is rendered very complete and permanent.

Sometimes, too, an unexpected deluge of mud is brought in through the water-supply, which, in a very short time, and almost wholly without notice, fills up solid the pipes, pumps, and heaters, and even finds its way into tuyere pipes and into boilers in hurtful quantities. Against such damage as this no guard can be maintained so effective as that of an open filter of ample area and fitted with these plain attachments. If the water needed for boilers is at all charged with oily matter, a good sand filter may be relied upon to remove a large

part of this hurtful element, which, in many instances, has led to the formation in the boiler of a flocculent deposit upon the more highly heated plates, and to their serious injury by its non-conducting power.

Careful attention has been given to this subject by railroad managers for the protection of their locomotives, but, as the quantity consumed in this service is comparatively small, an important part of the purification of the water may be effected by giving it time to settle in a tank. There still remains, however, even after the matter mechanically suspended has been wholly removed, the frequent presence of salts of lime held in solution, and the incrustations due to these are often exceedingly troublesome to deal with. They are such, too, as cannot be eliminated except by heating, and then only in part; but these methods of purification at best are costly, and so quite apart from the purpose of the present paper.

In the first study of a location for a large works, the quantity of water is usually the first question to be considered, while the quality is held as secondary. This may be the more safely permitted if care be taken, in the outfit of the works, to provide the filtering fixtures needed to restore the quality of the water, if doubtful or bad, to a normal and reasonable standard. In any case, the cost of this part of the general apparatus may very justly be taken as an investment for the insurance of the more costly parts of the machinery against one of the causes of injury, from which delay and damage may result. In all the strictly modern works improved appliances are to be found in many of the departments, and improved methods of working are continually sought for and adopted. The use of filtered water, when it can be had at so trifling and quite nominal a cost, is one of the steps in advance in the management of the great masses of steam and other machinery of the present day, and it is worthy of a more careful consideration and more frequent adoption than it has received. With the tendency to constant advance in steam pressures, in temperatures in and around furnace pipes and fixtures, and in the crowding and driving of hydraulic machinery in general, there is need of the use of the very best water-supply that can be had, for the best, whether from natural or artificial sources, is in no way too good for the intense service required.

THE SUGAR BEET INDUSTRY.

By Lewis S. Ware and Robert Grimshaw.

A Paper presented at National Tariff Convention, New York, Nov. 30, 1881.

The futures of nations and inventions are difficult to predict, both being controlled by unknown causes. Who, during the prosperous days of the Byzantine or the Roman empire, would have thought that a few hundred years would have swept it almost totally out of existence? Who, again, could have predicted, during the reign of George III, when this important English colony became independent, that it would later on be the leading nation of the world? What would prehistoric peoples have thought of the possibility of our recent scientific discoveries? In the same line of argument—what have these coming years in store for us? Is a foreign blockade of our eastern coast possible, or are Southern or Western difficulties near at hand? We cannot foresee. Whatever occurs, the commodity in greatest demand should be the first thought of. In the present condition of our commerce, sugar is the greatest imported commodity, and to that so-called luxury we should give our first thoughts. In the South the total sugar made in 1880 was about 200,000,000 pounds, while our total consumption was about 2,000,000,000 pounds; thus in round numbers, we rely upon other countries for nine-tenths of all the sugar we consume, at a present annual outlay of nearly $100,000,000. Whatever occurs, the Southern production is ample for Southern requirements. By present treaties with the Sandwich Islands, their Pacific sugars enter our ports free of duty, thus practically rendering the Western markets independent of the South, while under the present conditions, the Northeastern States have nothing upon which to rely in an emergency. Is not Northern sugar production desirable? Napoleon I foresaw the importance of protecting France, from a sugar point of view. His method, said the great Thiers, "thrice saved the country from ruin." We propose that America follow it, ignoring the unknown future and examining the present conditions of our sugar-growing interests. We notice that in our ninth decade, 28 pounds of sugar per capita per annum were consumed, while, from the present appearance, by the end of the eleventh decade it will be over 50 pounds

(this is 10 pounds less per capita than is consumed to-day in Great Britain). Our reasons for supposing that it will reach that figure are, that statistics prove that annual sugar consumption per capita increases with population and material wealth. In our tenth decade, it was nearly 40 pounds per head, and if our population should increase at the present ratio, there will be in 1890, 60,000,000 people consuming perhaps 3,000,000,000 pounds of sugar per year, which would possibly be worth, at 7 cents per pound, $210,000,000. If our production at that time is only one-fifth of the consumption, or three times the present production, barring unforeseen circumstances, it would be only 600,000,000 pounds; leaving 2,400,000,000 pounds to be imported. This would be worth, at 7 cents per pound, $168,000,000, sufficient to give yearly employment, at two dollars per diem, to 300,000 men; giving our own population the benefit of that home circulation of bullion. Such are the possibilities of the beet sugar industry ten years hence. If we examine into the present consumption, importation and exportation of sugar, we find that we consume 1,601,200,417 pounds of foreign origin, and only 198,945,420 pounds of domestic production, representing a total of 1,800,145,837, say 38 pounds per capita. In 1880 we imported 1,829,302,684 pounds, and exported 10,498,202; the difference between imports and exports being 1,118,804,482 pounds, of a total value, including foreign customs, of $118,749,743. The home production as compared with our population is considerably less than it was before the war; for then, with a population of 30,000,000, it was 302,299,105 pounds, or 10 pounds per capita; while in 1880, with a population of 50,000,000 it is but 264,000,000 of pounds, or 5·2 pounds per capita. This may, no doubt, seem paradoxical, but is true. The levees, which before the war protected the Louisiana plantations from the overflow of the Mississippi river, have in large part been destroyed. They could not be rebuilt for millions—perhaps hundreds of millions—of dollars. If we examine the sugar production of other Southern States than Louisiana, we will find that in South Carolina there has been an immense falling off in ten years, while in Mississippi it is now but nine-tenths of what it was twenty years ago. In 1860 the production in Louisiana was one-third of the total consumption in the United States; to-day it is much less. Yet our gross consumption of foreign sugars has more than doubled in twenty years, being in 1860, 660,777,673, and in 1880, 1,601,200,417 pounds. The consumption of home sugars has consequently decreased

nearly 1,000,000,000 of pounds. Such are the extraordinary fluctuations of our most important commodity. Is it not imperative that we look before it is too late to some other source than the cane for our sugar supply? Many of our sugar refiners and brokers, whose principal trade is carried on with Cuba, etc., offer considerable objection to home sugar production, but we fail to see where their interests would be in any way impaired; especially as within a few years slavery is to be abolished in Cuba. Are we not especially favored for home sugar production? Will the commerce existing between the United States and Cuba be as great after slavery has been abolished as to-day? If those foreign sugar-producing countries should no longer exist, we are convinced they would in no way diminish the interests of our refiners, who would then be interested in our home sugar production, which they are not, to any extent, to-day, being in many cases interested in sugar plantations outside of their mother country. Yet their direct refining business is practically less to-day than it was prior to the introduction of improved methods upon these sugar plantations.

The question of transportation from foreign shores and the placing of sugar upon the market at the most desirable time is an item that should not be overlooked when this grand sugar question is discussed. With the sugar beet, for example, refined sugar might be produced from the root and placed upon the market at least one month earlier than either foreign or domestic cane sugar, thereby realizing the greatest profit at the season when sugars sell highest. The importance of having a minimum freight upon a merchandise is indisputable; yet in the Southern States the sugar cane can never fulfill this condition, and climatic conditions do not permit the maturing of the sugar cane in the South until at least one month later than the sugar beet in the North. In European countries, where these difficulties were realized, they sought some other plant than cane for supplying their home sugar. Many were resorted to in 1800; sorghum and maize were tried, but attempts at their utilization were soon abandoned. Yet, completely ignoring the experience of those older nations, we have, in consequence, spent hundreds of thousands of dollars in theorizing and in experiments with sorghum and corn stalks, yielding absolutely nothing. A recent pamphlet by Lewis S. Ware, "On the Various Sources of Sugar,"* reviewed the five thousand experiments made by

* Published by Henry Carey Baird & Co., 810 Walnut street, Philadelphia. 8vo.

our Agricultural Department at Washington, and showed that very little over three per cent. of sugar could be extracted from sorghum and none from corn stalks. Is not this contemptible yield sufficient to condemn these alleged sugar-yielding plants? In all cases, the impurities in the sub-varieties of sugar cane prevent the crystallization of their saccharine juices. Hence the impossibility of extracting as sugar what sucrose they might possibly contain. Even if these insuperable difficulties were not to be contended with, we should condemn these plants, from which the cane sugar disappears within fifteen days after cutting rendering storage impossible, and economical manufacture impracticable. Again, the entire subject of sorghum and corn stalk sugar is yet in its laboratory stage, doing little toward solving the grand problem of manufacturing the sugar we consume. If we consider the maple tree, the idea of its utilization on a large scale is ridiculous. The same may be said of all other sources, the sweet potato, etc., from which, outside of the laboratory, nothing has been or can be obtained. But the sugar beet furnishes to-day nearly one-half the sugar of the civilized world. Many assert that beet sugar making in this country is impossible, basing their assertion on past failures, without looking to their causes. Efforts were made to introduce beet sugar making into the United States as early as 1829, a factory being established in Livingston county, and subsequently removed to Stevenson county, Ill. In 1869 the German Beet Sugar Company was organized at Chatsworth, Ill. In 1866 Fond du Lac, Wis., had a factory, which was moved to Alvarado, Cal. In 1870 the Santa Clara Valley establishment, California, was organized, but this was moved to Black Hawk, Wis. In 1878 the Portland, Me., factory was started, but it has been divided up—south, east and west. In 1879 the factory at Franklin, Mass., was established, and we now hear talk of moving it to Schenectady, N. Y.

Throwing aside our possible personal prejudices in favor of the beet-sugar industry, we appeal to the American people for fair judgment on these failures. It is rational to suppose that if these so-called beet-sugar factories, organized, in nine cases out of ten, by those not having the slightest idea of the requirements thereof, and failing in consequence, had been started in Europe by the same persons, and with the same limited capital, they would there have met with the same results. We cannot here in a few lines recall the whys and wherefores,

but will only say that all future establishments of this kind started with a capital of less than $200,000, or far from the centre of demand, or where water and fuel are not cheap and abundant, or where the technical manager does not understand in every detail the workings of the establishment, will inevitably fail. On the other hand, if correct principles be followed, success is almost guaranteed in advance. We have only to cite two recently organized existing factories, one representing Western enterprise and the other Eastern, which are wonderfully deserving for their perseverance, and which are manufacturing excellent sugar. One of these (the Alvarado factory) is dividend paying.* Its sugar is a staple article on the San Francisco market, where it successfully competes with that from the Sandwich Islands. The Delaware Beet Sugar Company, near Wilmington, expects to manufacture this year at least 150,000 pounds of sugar. The Alvarado Company has excellent beets; its sugar product for 1881–1882 is yet unknown, but will doubtless greatly exceed that of the past. Now, here we have two sensibly organized factories that meet with success, while the illy-placed, under-capitaled and ignorantly managed establishments have passed out of existence. What would be thought of moving a large Brooklyn sugar refinery two or three hundred miles from where it is now standing? It is not equally absurd to transport a beet-sugar factory? Yet all these difficulties are not greater than existed in Europe during the early stage of beet-sugar making. As far back as 1747, the great Prussian chemist, Margraff, called attention to the sugar existing in the beet, and the possibility and importance of its extraction. In 1830 some few sugar factories were working. In 1846, nearly a century from the date of its discovery, 100 beet sugar factories were started in the face of opposition of all kinds. From that time until 1860 the questions of home taxation, foreign colonial interests, etc., threw great obstacles in the way. In other words, it took over thirty years in France to establish this beet sugar industry on a proper foundation. But to-day what is the result? There are in Germany, Austria, France, Belgium, Holland and Russia no less

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* We have seen, since the above was in type, a letter from Mr. E. H. Dyer, Superintendent of the Alvarado Sugar Refinery here referred to, addressed to Mr. L. S. Ware, in which he communicates the gratifying information that as the result of their year's work, the establishment has earned 20 per cent. upon its capital stock, or 30 per cent. upon the capital actually invested. W.

than 1,500 beet-sugar factories, with an annual production of nearly 3,000,000,000 pounds, and there is no possible reason why we should not avail ourselves at once of the results attained by those older countries in a long series of experiments. If we are to consider as impossible the establishment of the sugar beet industries in the United States, we can no longer consider ourselves the leading—or even a leading—country of the civilized world; and with all our advantages of cheap land, favorable climate, ample capital, intelligent labor, and time-saving, labor-saving and money-saving devices—we had better take a back seat in the grand classification of nations.

But this problem will be commercially solved, beyond all question. within the next few years. The advantages to be derived from the manufacture of all the sugar that we consume are of an importance that can hardly be realized at first thought. It would render our country industrially and politically independent as regards the most important of commodities. It would introduce a new system of farming, much needed in the New England States. It would place milk, butter, cheese, lard, pork and beef upon our market in still greater abundance, to the advantage of our laboring classes and of our export trade To supply the United States with 2,000,000,000 pounds of sugar would occupy 1,000,000 acres of land per year, and, making allowance for the desirable rotation of crops, it would be indirectly the means of working at least 4,000,000 acres. The yield of beets would be about 20,000,000,000 pounds. Their manufacture into sugar would consume over 4,000,000,000 pounds of coal; we would have 6,000,000,000 pounds of pulp, representing 35,000,000 pounds of meat. Besides the meat, the manure resulting from feeding cattle on the pulp would be 2,800,000,000 pounds. There would be over 1,000,000,000 pounds of molasses, from which could be made over 32,000,000 gallons of alcohol at 96°B. Employment would be given to nearly 300,000 men, women and children. We would thus give a new market for such materials, consumed or resulting, as coal, bone-black, limestone, matches, brushes, leather, plaster, oils, lubricators of various kinds, sulphur, sulphate of iron, salts of ammonia, soda, bisulphite of lime, muriatic acid, wire of all kinds, rivets, bolts, zinc, tin, borax, tar, oils for various purposes, etc. Besides, there would be needed millions of pounds of iron for construction and for various machines in and out of the factory, and hundreds of millions of bricks

for factory buildings. We would give employment to engineers, chemists and many other branches of industry, and largely increase the demand for hundreds of home products. Further, this would gradually increase the yearly freight traffic on railroads, water-ways, etc. The country at large would be benefited under the circumstances. We do not know but that governmental encouragement would be desirable. We could then have the very best machines and the highest talent in the best possible location, all of which could not so well be realized under existing conditions. Individuals having property to sell offer arguments in favor of beet cultivation in their particular localities. Overlooking the most important of all other facts, that of probable sugar exhaustion, what would be the possible sugar result? While these lands might be desirable for the cultivation of grain, they might be disastrous for that of sugar beets.

In conclusion, we would say that no less than three factories will be started in Canada in the present year. These, however, are not Canadian enterprises, but started by foreign capitalists who have sufficient forethought to realize that there is money in sugar beets on this continent, notwithstanding unthinking American arguments as to former failures, which prove nothing against intelligent beet sugar making.

Are we, the people of the United States, to wait for foreign capital to establish among us beet sugar making on an extended scale; or are we to take immediate action, and prove to Europeans that we are capable of taking care of ourselves without their capital by prudently availing ourselves of their past experience, which we have heretofore so frequently overlooked?

We demand, then, that American farmers shall essay the proper cultivation of sugar beets for cattle feeding, and sugar and alcohol making; that American capitalists shall undertake beet sugar and alcohol making under proper auspices, in favorable localities, and with sufficient capital; that state and county premiums be given for the largest and for the richest beet crops, and for the first commercially successful beet sugar factories and beet alcohol distilleries; and that a fostering government give such rebates upon home Northern sugars, and such appropriations for ample researches, experiments and reports as shall enable us within ten years to freight our out-bound ships with sugar from the North, to sweeten the great eastward-bound grain and flour product of the new Northwest.

RECENT IMPROVEMENTS IN THE MECHANIC ARTS.

A novel invention, which has for its object the automatic setting out of the packing rings of a piston-head within the cylinder, has been devised by the Master Mechanic of the Pennsylvania R.R. Co. and will be adopted by that company for use on their locomotives. The improvement consists of a solid piston-head suitably cored out for the reception of the packing rings and their actuating levers, as also for the two adjustable bolts which centre the piston and provide the bearings against which the weight of the piston exerts itself to set the packing out automatically. The two operating levers are each fulcrumed in a block resting on the packing rings at the bottom of the piston and extend, one on each side, into the upper circumference of the head, where they rest against other blocks having their bearings on the packing rings and constituting the *resistance* of the levers. The *power* is applied through the two threaded bolts referred to and which work adjustably in screw bearings in the solid head. These bolts are each arranged on an angle of 30°. Thus, it will be seen that the whole weight of the piston rests upon these two bolts which, in turn, bear respectively against their levers, whose fulcrums are in the bottom of the piston and whose resistances or operating ends are in the upper part of the piston, whereby the weight of the same is utilized, through said levers, to bear directly against the upper circumference of the packing rings to expand the same in the upper part of the cylinder.

A recent improvement, tending to increased safety in railroad travel, consists of a frangible tube projecting from the cab of a locomotive and communicating with the brake-pipe of the Eames or Westinghouse system of air-brake apparatus. A switch, drawbridge, etc., have wires or ropes attached to them which lead to semaphore arms arranged at a distant point on each side of the switch or draw. These semaphore arms are so arranged that when a switch is misplaced the arms will lie across the path of the frangible tube on the locomotive, whereby said tube will be shattered and the brakes instantaneously applied. In the Eames improved system, a constant vacuum is maintained in the brake-pipes, the brakes being set by the destruction of the vacuum, which has the effect of opening up the vacuum power of auxiliary reservoirs located under each car; thus, it will be observed that the breaking of

this frangible tube will destroy the vacuum in the brake-pipe. In like manner, in the Westinghouse system, a continuous pressure of air is kept up in the main brake-pipe, the reduction of which opens up secondary reservoirs under each car, which operates the pistons of the brake apparatus.

A late invention provides means for extinguishing fires in the stoves of passenger cars should they, by any accident, upset. For this purpose an elongated water-reservoir is suspended along the side of the car. Cords, attached to the stove and to valves which normally close outlets in the reservoir, serve to operate said valves when the stove is upset, and allow the water, through a perforated distributor, to flow into the fire.

A new staple of manufacture consists of the fibre of the stalks of cotton plants. The stalk is disintegrated and the fibre separated from the rest of the stalk, preserved and prepared according to the following method: First separating the fibre from the stalk by passing through rollers or by retting, then drying, then scutching or breaking, and then carding or hackling the same, thus producing a staple of the fibre alone. It is proposed to manufacture from this staple woven fabrics by spinning it and converting it into twine, cordage and yarns, wadding, packing, calking and paper. F. B. Brock.

Washington, D. C.

CORRESPONDENCE.

The following correspondence, received by the Secretary for presentation to the Institute at the stated meeting in March, has been deemed of sufficient interest to warrant its publication:

THE HUDSON RIVER TUNNEL.

Secretary of the Franklin Institute:

Dear Sir—In forwarding you the following memoranda of progress and experiences of the past year, I would say by way of introduction that there is but little that is curious or novel in it that has not also been the experience of similar undertakings, or rather so much of others as resemble it from any aspect, viz., that of working under a pressure greater than normal atmospheric pressure; in this a record of what occurs here would be much the same as numerous well-told

experiences of sinking pneumatic caissons show; and of tunneling, generally, surely enough has already been said, while of a combination of these processes there has but little come under our observation so far, and but little can we now add.

It is assumed that you are sufficiently well acquainted with the general features and scope of the enterprise, and only a statement of its magnitude is here offered, viz.:

Two tunnels, both as to grade and alignment parallel, as near as may be; each to accommodate a single line of rails; east and west bound traffic.

Length of tunnels from shaft 83 feet, inboard on New Jersey shore to caisson 90, inside of bulkhead wall on New York side of the river 5500 feet.

Approaches at either end about 4000 feet each. Greatest depth of water overhead at mean tide 60 feet.

Operations were begun in 1874, although but very little was accomplished, owing to litigation, until August, 1879, since which time the work has been carried on continuously.

The inauguration consisted in sinking an open shaft, 30 feet internal diameter, with walls 4 feet in thickness, to a depth of 60 feet; at a depth of 40 feet an angular opening was made in the side of the shaft, and one end of an air-lock inserted, and the excavation began.

Up to March 1st, 1881, some 260 linear feet had been completed in the north and 250 in the south tunnel, when it became apparent that too much duty was put upon the compressors to maintain the required pressure, owing to numerous air-leaks, of greater or less dimensions, and it was decided to erect in each tunnel a bulkhead of somewhat permanent character, move the air-lock forward to this bulkhead, thus reducing the size of the air-chamber and consequently the volume of air supply necessary to keep up the desired pressure.

But it was deemed best not to let off the pressure at the headings while this was done, which involved the construction of air-locks in pieces that could be passed through the lock in the side of the shaft, the doors of which were 3 feet by 4 feet.

This, it is believed, happened to be the first instance where an air-lock was made in so many parts, and erected under pressure. The specification is enclosed, and it need only be stated here, what is obvious on inspection, that they have proved entirely satisfactory.

In the meantime the work was pushed forward until 450 feet in

each tunnel had been completed, when the bulkheads mentioned were built 420 feet from the shaft, the air-locks set up in them, as shown on sketch, and in place of one large air chamber (in all about 900 feet long), it was possible to change to two, each only 30 feet in length.

Previous to this change there were three air chambers, of which I send you a sketch, which requires no further explanation, except it may be stated that the pressure west of the bulkheads was kept at 15 to 18 pounds, in the north heading 18 to 20, and in the south heading 22 to 24 pounds per square inch above atmospheric pressure. This, however, required too much care and attention, and a decision was finally reached to allow the pressure west of bulkhead to fall to normal condition, and on August 11th the men were brought out of the heading, and the air allowed to escape from as many openings as could be made through steam, air and water pipes leading to or from this portion of the work. About an hour was required for the pressure to run down to 1 pound per square inch as indicated on the mercury column in engine room; no further decrease could be gained, owing to leakage from the other chambers, and the door of air-lock was forced open with a hydraulic jack, and Mr. D. C. Haskin, the originator of the tunnel, entered without the process of "locking" through.

Shortly after, however, the door of the old lock was closed. As the bulkhead in the north tunnel had been but recently built it was thought best not to subject it to a pressure of more than 20 pounds to the square inch, and orders were given to let the pressure in the headings run down to that. When the pressure was let off from the main part of the tunnel there was far more air leakage through and around the bulkhead walls than was anticipated, so that the pressure ran still lower, though the compressors were run at as high speed as was consistent with safety. The reduced pressure in the south heading was not sufficient, and the silt moved slowly in some 25 feet.

The bulkhead walls were of brick, four feet in thickness, backed by a solid timber wall of yellow pine, 12 inches by 12 inches, and strongly braced, as shown on sketch. Two locks were set up in each bulkhead, either of which would contain all the men engaged at any one time in the heading, and instructions given to keep one of them at all times open in that direction, in order to secure a retreat for workmen in case of accident resulting in an influx of material at the heading that could not be controlled. This probably increased the

confidence of the men—if, indeed, it were necessary—although subsequent experience seems clearly to prove that no probability exists for this precaution, as the silt moves very slow when entirely relieved of pressure from within the air chamber. Two locks are recommended, however, in similar cases, entirely from an economical point of view, making it possible to pass materials, either of excavation or for construction, through them with so much greater expedition and convenience.

Previous to the construction of the bulkheads the excavation was carried on by mixing the silt with about 25 per cent. of water, and forcing it out with air pressure, as the usual practice; since then, however, until the 1st inst., the excavated silt has been removed by an "Eads sand pump." This gave good results, taking out sometimes as high as 30 per cent. of silt, but in consequence of the great distance there began to be indications that the limit was approached. At this time a "silt pump," designed by Mr. Chas. W. Clift, M.E. of the tunnel, was tried and found to be very satisfactory until the present time, and, being a simple, straightforward contrivance, was much liked.

The experiment is now being made of removing the silt from the heading in its natural condition, and as yet it is impossible to state as to the relative economy. The hydraulic method of excavation was rapid, but considerable inconvenience was experienced from the waste water; on the other hand, in sending the silt out dry it requires more handling, but leaves the heading in much better condition for putting masonry in.

Of the temporary entrance from the shaft to the tunnels there yet remained a short wedge-shaped section to be constructed, and which had been under consideration during the whole year, 1881, and of course various methods had been proposed, freely discussed and criticised, and rejected. The writer, fortunately, was the author of the last plan suggested, which was adopted, and which consisted in simply closing the doors of the old air-lock, increasing the pressure within again, and drifting westerly from the chamber joining the tunnels to the shaft.

Thus two short sections of tunnel were built without noteworthy incident, unless perhaps mention may be made of the relief afforded by pumping from the stand-pipe in the shaft some 25 feet distant,

which appeared to reduce the pressure, and at all events the volume of water when the excavation was going on.

It may be better, by way of explanation, to state that it was necessary to remove nearly all the overlying silt at that point and expose the water-bearing strata of sand, and also that during the three weeks that the above work was going on, a horse was kept continuously under a pressure averaging 10 pounds per square inch above the atmosphere. A loss of horse-power was calculated but, like many other well calculated plans, they went astray (for the horse still lives).

Now of the processes in vogue at the heading, the manner of advancing or driving the pilot forward may first be considered.

The pilot is 6 feet 6 inches in diameter, made up of 10 plates in each ring about 2 feet wide by 3 feet long, with angle bars 4 inches by 4 inches by ½ inch on the inside for bolting the plates and successive rings together.

The operations are first to make an open cut in the heading of sufficient size to admit one plate, which is supported by bracing from the bottom of the cut, another cut is then made at one side and a second plate put up and bolted to the first, then a third plate is put up on the other side of the first, and other plates are added on alternate sides, working downward until the ring is completed.

Then a second ring is put up in advance by a like procedure, it is also securely bolted to the first ring; work in driving the pilot forward is kept up until a distance of about 40 feet beyond the heading is reached, when the work is suspended to allow the finished tunnel to overtake the pilot, when work on both pilot and tunnel will be carried on simultaneously.

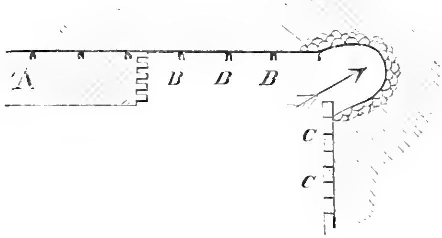
The back end of pilot usually extends 10 feet or more into the completed tunnel from which it is firmly held by braces. The forward end being well advanced into firm silt, it is practically immovable and, together with its advantage as an exploring agent, it forms a kind of bridge or brace against which radial braces are set to hold the iron shell in place while the masonry is being built.

After which uses the rear rings are taken down, carried forward and bolted on at the front end to do duty over again.

The iron shell of tunnel is put up in much the same manner, except that these plates remain as a part of the structure.

There have been, however, several occasions when the following novel and somewhat difficult undertaking has been successfully per-

formed, viz., that of making an opening of the required dimensions to insert a plate without excavating any material; this would occur when soft silt was encountered or, as we call it, when from any cause the heading became "demoralized."



The following figure may assist somewhat in making the description clearer, where "*a*" represents the end of finished brickwork, "*b, b*" rings of the iron shell, "*c*" a temporary bulkhead of 4 inches by 6 inches timber or sometimes 2 inches plank doubled. But the work must go on, and a hole is cut in the bulkhead large enough to admit a man's hand. Instantly the silt begins to ooze in and the air to escape. But a man stands ready with balls of quite dry silt, brought in for the purpose, from 4 to 6 inches in diameter, which were rapidly plastered into the soft ooze and pressed back; thus the progress of the silt was stayed. Carefully one ball after another was inserted of this puddle and gently pushed backward until a kind of skin or shell was formed of it; these successive additions being pressed together until an air-tight concavity had been made.

Then a gentle onward motion was given and continued till the opening assumed dimensions sufficient to put up the plate, which advanced the heading 2 feet 6 inches by 4 feet of the circumference.

Occasionally the skin of puddle would become impaired and the soft silt force its way past the hand; then the air would escape in considerable volume with a sound peculiarly suggestive and threatening (should be heard to be appreciated), bringing all hands and the liveliest kind of work to repair the breech. Sometimes it could be repaired with one or two more balls of the hard silt, at others bags of sawdust and short pieces of plank and anything that came to hand had to be used. But the excavation would be made and the plate put in place without taking any material from the heading, although 4 hours' work of 12 to 15 men would now and then be required.

Again the pressure of air required for carrying on the work by the

pneumatic process is determined chiefly from day to day by actual observation, although the theoretical pressure due to a column of water of the height or depth of the work is a very close approximation, and this is varied only as the silt becomes soft or dry and flaky. If the former the pressure is increased from $\frac{1}{4}$ to $\frac{1}{2}$ lb. per square inch, if the latter the pressure is reduced, the maximum variation not exceeding three pounds per square inch.

I send you also a number of sketches which you will understand without any further explanation, and trust you may gather from them and the foregoing something indicative of our methods and some of the secrets which have been vouchsafed to us in our "digging" up to the present time, in which we now have to our credit nearly 1400 lineal feet of completed tunnel. S. H. Finch.

New York, March 10, 1882.

Specification for Air-Locks.

Each "lock" to consist of a cylindrical main body.

Inside diameter 6 feet, inside length 15 feet, in 5 rings of 2 plates each. To each plate is riveted an angle bar $\left\{\begin{matrix}3\frac{1}{2}\\3\end{matrix}\right.$ inches by 3 inches by $\frac{3}{8}$ inch, the outside periphery same as plate, longitudinal faces of same to lie in the direction of radius of shell, and transverse faces to be perpendicular to axis of cylinder. Rivets $\frac{3}{4}$ inch diameter, 2 inches "pitch," and holes for $\frac{3}{4}$ bolts $2\frac{1}{2}$ inches "pitch." Heads and nuts of bolts to be hexagon.

The ends of shell to be $\frac{1}{2}$ inch thick, in two pieces, each with angle bars riveted to both sides of plate, and provided with doors with true surface, 2 inches wide, running around outside edge of door, and corresponding seat, $\frac{1}{2}$ inch in thickness, riveted to heads of cylinder with countersunk rivets. Doors to be stiffened with 2 "T" irons, 3 by 4 by $\frac{1}{2}$ inch, and provided with hinges, latch and handle as shown.

Stays or straps, 15 inches by $3\frac{1}{2}$ inches by $\frac{5}{8}$ inch, are required on inside of shell placed 12 inches from centre; holes in shell bored to draw $\frac{1}{16}$ inch.

The following pipes are also required, each end to be fitted with packing glands:

1 air supply pipe, 3 inches inside diameter.
6 water and steam pipes, 2 inches inside diameter.
2 equalizing pipes, $1\frac{1}{2}$ inches inside diameter.
1 blow-out pipe, 6 inches inside diameter.

One 8-inch bull's-eye in each door to be inserted. Plate of C No. 1 iron.

Coppering Iron.—For the past ten years M. F. Weil has been testing specimens of cast and wrought iron and steel which have been coated with copper by his methods, without requiring any intermediate deposit or any finishing touches. The homogeneity of the deposits reproduces the most delicate details of ornamentation, so as to give the articles the artistic value of bronze. The cyanides, which are injurious to the health of workmen and which greatly increase the cost of coppering, are replaced in his methods by organic acids or by glycerine, materials which are cheap and which have the advantage of not being decomposed. The baths require no renewal of organic materials, provided they are properly supplied with oxide of copper. The well-known property of alkaline-organic solutions, of rapidly dissolving oxide of iron without attacking the metallic iron, facilitates the perfect cleansing of the pieces. When the oxide of copper requires renewal, the exact amount which is needed is determined by a very easy test. Various other metals, such as nickel, cobalt, antimony, tin, etc., can be deposited upon iron and other metals by his processes.—*Comptes Rendus.* C.

Improvements in Bleaching.—A medal has been awarded by the Societé Industrielle de Mulhouse to Charles Weber & Co. for bleaching cotton thread upon bobbins and spools without passing through the various customary processes. Their method enables them to reduce the cost from 25 to 40 per cent., according to the fineness of the thread. They are thus able to export their products into various countries where they could never have been sold in a crude state. They use great monolith vats, of a cubic form and with a capacity of six cubic metres (7·848 cubic yards). The spools, carefully packed, are placed in these vats, which are then closed by granite covers hermetically sealed. The heavy covers are easily managed by means of overhead traveling cranes. The spools are completely bleached in these vats, from which they are removed to improved dryers. Pure water being one of the indispensable conditions for their process, they bored a well with which they connected a forcing pump and filters. The pump is so constructed that it can also be employed for extinguishing fires. The washing and bleaching waters are rendered inoffensive by passing into four great cement wells where they deposit their impurities. Many American improvements have been introduced in their machinery.—*Bull. de la Soc. Industr.* C.

Influence of Electric Light upon Plants.—The experiments of the Champs Elysées have shown that elestric light alone is sufficient to maintain life for two months in plants which are accustomed to the light of the open air. Prof. Dèherain rrecommends that investigations should be undertaken to determine by what methods the light may be most advantageously employed in greenhouses. It is especially desirable to inquire whether the incandescent lamps, which give a yellowish light, are not probably richer in radiations that are favorable to vegetation than the violet light of regulators. The solar lamp, in which the light emanates from lime that has been made incandescent by the electric arc, is probably richer in useful rays than the arc itself. —*L'Electricien.* C.

Influence of the Choroid upon Keenness of Vision.—Most physiologists have assigned to the choroid merely the office of absorbing, by its layer of pigment, the luminous rays which have traversed the retina, so that they may not be reflected towards the pupil. They compare the pigment to the black varnish that is used in the interior of optical instruments. M. Fano thinks that its vascular structure is designed for bringing to the retina the greater part of its nutritive elements, and he believes that he has shown, by numerous experiments, an important influence which it exercises upon the sharpness of vision. Patients who are afflicted with an atrophy of the choroid are generally short-sighted. If this defect was owing merely to a peculiar state of the refracting media it could be remedied by suitable glasses. There are many cases which cannot be be helped by artificial means. In every such instance it is probable that careful observation will detect alterations of the choroid membrane.—*Les Mondes.* C.

The New Fountain of Milan.—E. Paladini has published some notes upon the hydraulic works for the use of the Industrial Exposition and of the new fountain of Milan. The total cost of the works was 80,000 lire ($16,000). The daily supply of the fountain costs nine lire ($1.80). The water is thrown to a height of 27 metres (29·528 yards), with an expenditure of 34 litres of water (8·975 gallons) per second. The effect is quite as striking as that of either of the other great fountains of Europe. The Berna fountain consumes 70 litres per second; the Trafalgar Square, 64; the Stoccarda, 62; the Turin, 50; each of the fountains of the Place de la Concorde, 61; each of the Rond Point, 36; that of the Place Belle Court, 40, and that in the Place du Chateau, Bruxelles, 40.—*Il Politecnico.* C.

Steamer "Phosphor-Bronze."—An English company has built a steamer of phosphor-bronze, to which it has given the name of the metal. The length is 10·5 metres (11·393 yards) and the breadth 1·8 metres (1·969 yards). On its experimental trip it gave a velocity of 12½ miles, which is a rapid speed for a boat of its size. The object of the company in constructing so small a vessel was to test the rigidity of phosphor-bronze, both in plates and angular pieces, before employing it for larger boats. The results are more satisfactory than were anticipated. The cost will not much exceed that of iron or steel, and as the bronze does not corrode, the value of the raw material will be preserved.—*Gaceta Industrial.* C.

Borate of Soda.—M. Widemann finds that if 12,000 kilogrammes (12 tons) of soda are dissolved in 2000 litres (528·37 gallons) of water and the solution is saturated with boric acid or *tinkal* and then boiled, a borate of soda is produced which has five equivalents of water, while ordinary borax contains ten. If borate of soda is calcined and melted in a crucible and then poured upon a plate of glass or very dry stone, it may be pulverized and placed upon a piece of damp linen or unsized paper, when there is a very rapid elevation of temperature to about 80°C. (176°F.). This property may be employed for producing a warm poultice with cold water, without danger of burning or inflaming the skin, or for warming food, etc.—*Chron. Industr.* C.

Last Eruption of Mauna Loa.—The late eruption of this volcano was the greatest that has been observed for fifty years. The lava flowed regularly and without interruption for nearly nine months and a half. A cloud commonly rested over the hot lava, which was doubtless formed, like ordinary clouds, by the ascending heated air, which was loaded with invisible vapors that were condensed by the cold currents of the upper atmosphere. The condensed moisture, in descending, formed a kind of cyclone or water-spout, which was precipitated upon the incandescent lava and reduced again to vapor. As there were commonly many square miles of lava at a red heat, these storms were frequent and gave some faint idea of the disturbances which are continually taking place at the surface of the sun.—*Comptes Rendus.* C.

Hydro-Motors.—The city of Geneva furnishes water for small engines at 5 centimes per cubic metre (1 cent per cubic yard), under a pressure of $4\frac{1}{2}$ atmospheres, thus giving a horse-power for 35 centimes (7 cents) per hour. This is only half the charge that is made for water for domestic purposes. Two kinds of apparatus are used—one acting on the plan of the turbine, the other through pistons which are moved by pressure. The second seems to be generally preferred.—*Soc. des Ing. Civ.* C.

Book Notices.

STEAM HEATING FOR BUILDINGS. By Wm. J. Baldwin. New York: John Wiley & Sons, 1882. Second edition.

To do full justice to this treatise on steam heating, the writer of this notice felt impelled to refer by way of comparison to the most recent *previous* work on steam heating in the English (or any other) language, and took from his book-shelves the bound volume of Essays on the Economy of Fuel—the Effects of Heat and on Heating by steam. Robertson Buchanan, Glasgow, 1810. (Second edition, or enlargement from a pamphlet of 1807.)

It is difficult to appreciate that an entire industry could have had a progress and development of eighty to ninety years and remain without especial description or record, except what is to be found in this forgotten treatise of seventy-two years since. And with this absence of report of progress, it becomes peculiarly interesting to trace the degree of advance in principle or in apparatus which the two books indicate. For the principles involved, a discussion of which forms the first part of Buchanan's book and a portion of Baldwin's work, it is not sure that the older writer has not presented the more thorough and practical considerations, statements and tables, although his authorities are Belidor, Prony, Dalton, De Luc, Boerhave, Watt, Black, Leslie, Rumford and others, while Baldwin has Regnault, Rankine and more modern lights. (By the way, it should have been recognized by Baldwin that Rankine's formulæ were deductions from Regnault's data, sometimes modified to meet Rankine's thermo-dynamic hypotheses.) For the methods Buchanan treats, generally, of a quite dissimilar apparatus—that with cast-iron flange pipes, while Baldwin restricts his

discussions mainly to the practice of wrought iron pipe steam heating as employed for house warming, with a little of extension to other purposes.

The types of steam heating apparatus used in America are peculiarly American, especially the apparatus of small wrought iron tubes, which had its origin at the hands of the late Joseph Nason, between 1840 and 1850. The essential detail lying at the basis of this trade is to be found in the apparently insignificant feature of the taper screw thread, which gave a ready means of making a sure and perfect joint for pipes and *fittings*, which latter Mr. Nason devised and provided in so many forms, that little addition to their number has been made since his original inception. To be sure, the united ingenuity of hundreds of skilled and intelligent workmen has developed some improvements. But it is certain that in all mechanical growths a type becomes established in marked features, so distinctive that the deviations are merely subsidiary, and rarely essential or even important, except as facilities rather than necessaries; in this manner the American system of steam heating has grown from its original root.

As a record of practice at this day this work of Mr. Baldwin's is fairly representative. In some ways it might be extended, for the steam heating apparatus, particularly discussed, is the customary house apparatus, appropriately denominated a *low-pressure gravity circulation;* while larger or more extensive apparatuses are not so fully considered. The articles on boilers, grates and chimneys are much more general. Those on other applications of heat, as drying, cooking, hot water supply, again have incomplete exemplification. Even in the details of construction, where it might have been supposed that a practical work would have been very elaborate, there are some important omissions. Thus the universal box coil is mentioned only by name, not even illustrated or described, although alluded to frequently, while its innumerable modifications have at least the importance in general steam heating, that the changes of the vertical coil, so profusely shown, possess.

The approximate rule for computation of extent of heating surface is stated to be a square foot of heating surface to 100 cubic feet of space, with the addition of 15 to 30 per cent. for exposed or corner rooms, qualified by other considerations of quality of building, etc. Might not a qualification for character of surface be needed? It is probable that vertical surfaces of all kinds would have to be taken as

of less value than horizontal surfaces. Vertical tube coils should be admitted to be less efficient than box coils with equidistant tubes in equal numbers.

Although disarmed from caviling by the first proposition of the title-page and preface, that the work is intended as "hints to steam-fitters," rather than defined instructions, yet it may be fair in the interest of knowledge to remark on some points. The difficulty of controlling the temperature of steam-heated surfaces—steam of 212° and above, by throttling the steam supply to any particular extent of surface, does need mention, and the regulation of extent of surface by division into separate parts should be stated, with perhaps other ways.

As a matter of fact, the only changes in sizes of wrought iron tubes in thirty-three years, are found in the $3\frac{1}{2}$- and 4-inch tubes, which were originated in this country in 1849, one-fourth an inch larger than the English standards, and were made for fourteen years *over-sized.* Any other deviations of "old sizes" are errors of individual steam-fitters.

It should be fully recognized that the *air* difficulty is the most important obstacle to circulation to be encountered, and with this assertion, the methods of expulsion of air from the upright return pipes, systems 1, 2 and 3, of the illustrations, are not easy to comprehend. The usefulness of separating vessels, relieved by metallic air traps, at the *effective* water-line in returns partially filled could be insisted on.

Above all, the dictum that "*A building heated altogether by indirect radiation cannot be other than sufficiently ventilated*" will scarcely command unqualified assent. Systematic ventilation will remain a necessity, whether the heating is incident to a limited supply of air or not.

Whatever questions or subjects for discussion this book may open, its importance at this time cannot be denied, and the full appreciation of its merits by the steam-fitting public is given by the fact that in less than three months it has run out the first edition. R. B.

A New System of Ventilation. By Henry A. Gouge. New York: D. Van Norstrand, 1881. Fourth edition, enlarged with new illustrations.

The title-page declares this book to be "A Book of the Household" and bears the following quotation as a motto: "If we breathe a gas that is noxious, or air that contains a very small proportion of carbonic

acid, we die."—Anatomy, Physiology and Hygiene, by Professor John C. Draper.

The preface sets out "Theories of Ventilation have had their day * * * * Nothing is worthy to be called Ventilation that cannot *show by measure* the necessary number of cubic feet of air removed every minute the year around."

With such a commencement it may be supposed that the "new system" will establish definitely what is to be done and how to do it.

An innocent reader might question Prof. Draper's remark, and while admitting that all who breathe air will die, desire to know or to be told how small a quantity of carbonic acid will kill them. Mr. Samuel Weller's account of the clerk in a government office who tried the three shillings worth of crumpets, toasted 'em all, ate 'em all, and then blew his brains out, on principle, could be paralleled. People do die from suicide after visiting crowded beer gardens repeatedly. Perhaps the proportions of CO^2 imbibed and inhaled are *too large* to kill.

But what does the author himself give out to be the proper quantity of air for each person, for light, etc. "which a room is expected to contain" "for every day in the year, in spite of wind and weather?" Alas! the entire 170 pages octavo do not have a word to say on these points. It is apparent "theories have had their day" and only "the system" of supplying an unknown quantity remains. What a development of novel algebra this proposition discloses?

It is not fair to quote a few words of each work, and from the text to convey an unfair deduction, so there is now given a larger quotation from page 106 "What is, and What is not, Ventilation."

"Characteristics of Gouge's System.

"Our distinctive proposal is not simply to put up certain ventilating apparatus, nor to introduce such flues, etc., as according to the philosophy of heat and gases ought, theoretically, to create the desired movement of air; nor merely to remove, in a general way, such impurity or slowness of air as may be noticed by the senses. All such things as these are matters of opinion and doubt, and the most favorable estinction of them can be but indefinite. On the contrary, the definite, tangible thing we in all cases contract to do, and about which there can be no mistake or dispute is to exhaust (and replace) any prescribed volume of air per minute, whether 50 or 5000 cubic feet, at the outlet of each room, replacing the same continually with a like quantity of fresh air,

warm or cool to suit the season; and delivering the result by measure as that of the yard stick or bushel. This, and this alone, is what WE mean by Ventilation."

It would appear from the above that the Science of Ventilation (dropping the word theory) must hereafter rest on no authority or computation but on Mr. Gouge's guess. Far be it from the writer of the present notice to say that this guess may not be better than some people's hypotheses (not to say theory).

The next information to be derived from "a book for the household" is how to effect the ventilation thus "definitely established." This is set forth as follows "What then is our motive power?" "It is furnished by an ordinary argand gas burner, operating through a peculiar form of flue so constructed as to near the well known velocity of flames, or on inductive power, entraining [*sic*] through precisely adjusted orifices, copious current of air; such as we perceived when a flame is started with paper, straw, or shavings at the draft throat of any well-constructed chimney or stove." It is to be supposed that the word entraining is derived from the French "*entrainèr*," to draw along, as the proposition for formation of an air injector with the ascension of the heated current of a gas jet for central induction column implies the *drawing along* of other currents to some limited extent.

Now it is not to be gainsaid that this method (as old as the beginning of this century at least) will effectively induce an efflux from a source provided systematically, or surreptitiously, with a corresponding influx; but it cannot be admitted to be an economical method of producing the movement of any large quantity of air. Such as, for instance, would seem to be necessary or desired from a crowded hall for a long session. And the "system" would be found difficult to regulate if thirty or forty such *induction flues* took out of the same room or even if more than one flue thus discharged.

For the merits or demerits of this "system" in method this book notice does not seem called upon to discuss very fully. The merits are set forth completely by numerous testimonials of high respectability with a large number of references from which it seems impossible not to draw the inference that the author's practice is based on further data than he communicates to the general public, and that his success ought to secure him an extensive business in his profession.

R. B.

Franklin Institute.

HALL OF THE INSTITUTE, March 15, 1882.

The meeting was called to order at the usual hour, with Vice President J. E. Mitchell in the chair.

There were present 154 members and 28 visitors.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers and reported that at the last meeting of the Board 17 persons had been elected members of the Institute, also that, on the application of the following members, they had been authorized to constitute the Electrical Section of the Franklin Institute, viz.:

Robert E. Rogers, M.D.,	N. H. Edgerton,
Alex. E. Outerbridge, Jr.,	W. W. Griscom,
Wm. D. Sargent,	Horace W. Sellers,
Addison B. Burk,	Wm. P. Tatham,
David Brooks,	D. S. Holman,
Edwin J. Houston,	Wm. H. Wahl,

John J. Weaver.

Mr. W. Barnet LeVan then read the first paper of the evening on the subject of Rapid Transit—Past, Present and Future. The speaker described the gradual development of the methods of transit and offered some ingenious suggestions as to the possibilities of the future. He illustrated his remarks with the use of a number of lantern pictures. Remarks were made upon the paper by Messrs. Orr, Mitchell, Burk, Nystrom and Cooper.

Mr. W. U. Greene followed with a paper on the Mears Chlorination Process, a modification of Plattner's process of treating auriferous ores, the special peculiarity of which resides in the use of chlorine under pressure. The paper was discussed by Prof. Koenig and Mr. Grimshaw, and has been referred to the Committee on Publication for insertion in the JOURNAL.

At the request of the Secretary, Prof. Koenig made some remarks upon the Davis Process of Precipitating Gold by Carbon, describing his own experiments made with the view of ascertaining whether the action of the carbon was a chemical or physical one, or both. An abstract of Prof. Koenig's remarks has been referred to the Committee on Publication. Prof. Houston remarked that he had just been making a series of investigations into this subject and confirmed certain statements of the former speaker.

Mr. Chas. A. Moore, of New York City, next made some remarks upon the Nickel-seated Pop Safety Valve, invented by Mr. Geo. W. Richardson, and illustrated the subject with the aid of the lantern and by sectional specimens of the valves themselves.

Owing to the lateness of the hour, the President announced that the description of "An Improved Feed-water Heater," which was to have been made by Mr. Geo. S. Strong, had been postponed, by request, until the April meeting.

The Secretary, after referring to some interesting correspondence respecting the Panama Canal and the Hudson River Tunnel, confined his report to the description of a few mechanical novelties, a number being reserved for the next following meeting.

The Electro-Massage instrument of Dr. John Butler was shown and described. It combines in one apparatus the operations of kneading or manipulation of the muscles and joints with the application of electricity. It was sent for exhibitian by the Dynamo-Electric Manufacturing Co., New York.

An ingeniously constructed opera-glass was shown, with eye-pieces hinged to the frame of the apparatus in such a manner that when closed the opera-glass forms a single tube, making it much more convenient to carry, and when required for use can be readily opened in the form of the well-known double tube instrument. These glasses were sent for exhibition by Mr. W. M. McAllister, of Philadelphia.

A novel plan of insulating electric light wires by means of a series of porcelain buttons, making a flexible and indestructible insulating covering for the wires was also shown. The buttons are made of sizes to correspond to the size of wire or wires to be covered and are pierced with as many openings as there are wires to be strung upon one line. This mode of button insulation is intended for heavy as well as for light wires. Where the wires run in-doors, no further protection than the porcelain buttons is considered necessary; where the line is carried underground, it is recommended to carry in a metallic pipe and to fill the vacant space by forcing in some plastic composition like asphaltum. This insulation was sent for exhibition by Mr. P. B. Delaney, of New York.

A Motion Indicator, Regulator and Alarm was shown, designed for the use of flour and grist mills and all machinery where a certain and uniform motion is necessary in order to obtain good results. The apparatus operates by centrifugal force. A pair of governor balls,

when the speed is what it should be, rotate without alarm, but when the speed is either above or below that for which it is set, the balls strike a projecting arm or pin which communicates with a gong and rings a continual alarm. The number of revolutions is indicated on a dial. The apparatus was sent for description by N. P. Bowsher, South Bend, Indiana.

A number of samples of Rubber-covered Carriage Steps, for carriages of various styles, were shown. In these the rubber gives a soft, elastic treading surface, which being ornamented with ribs, etc., affords a secure foothold. These specimens were sent for inspection by the Rubber Step Manufacturing Company, Boston.

A specimen of an Anti-friction Bearing for shafting, carriages, team wagons, cars, etc., was described. The bearing surfaces were made of a series of hardened steel rollers. The inventor claimed by the use of this bearing to be able to dispense with lubricants and to save considerable power. This exhibit was made in behalf of John G. Avery, Spencer, Worcester co., Mass.

Mr. Robert Grimshaw, Secretary of the Mechanical Section, announced, under the head of new business, that the next meeting of the section would be held on Monday evening, March 20th, at which time there would be presented for discussion and action the very important subject of determining and recommending a national standard gear-tooth system, by which all gears of the same pitch, no matter what the pitch circle, should gear properly and truly together.

Mr. D. S. Holman made the announcement of a lecture to be delivered before the Phonetic Short-hand Section on Wednesday, March 22d, upon which the meeting was adjourned.

William H. Wahl, *Secretary.*

List of Books Added to the Library during January, February and March, 1882.

Abernathey, R. J. Practical Hints on Mill Building. Moline, 1880.
Presented by the Author.

Adjutant-General of Pennsylvania. Report for 1881. Harrisburg, 1882. Presented by Adjutant-General.

American Mail. Vols. 1—6. N. Y.
American Stationer. Vol. 7. N. Y.
Presented by Howard Lockwood, Publisher.

Annual Reports of Births, Marriages and Deaths in Michigan for 1874 and 1875. Presented by Superintendent of Vital Statistics.

Appleton's Cyclopædia. N. S., Vol. 5. New York, 1880.

Armengaud's Publication Industrielle. Vols. 11—27. Paris.

Baldwin, W. J. Steam Heating. N. Y., 1881.

Belgrand. Aqueducts Romains. Paris, 1875.

Black Hills of Dakota. Report on the Geology and Resources of. J. W. Powell, Washington, 1880.
Presented by the Department of the Interior.

British Patent Office.
Abridgments relating to Brewing. London, 1881; Music and Musical Instruments. Part 2. London, 1881.
Disclaimers for 1875—1880.
Specifications and Drawings. Vols. 21—41. London, 1880.
Subject Matter Index. London, 1881.

Building Construction. Notes on. Vol. 3. London, 1879.

Bureau of Education. Circulars of Information. Nos. 4 and 5. Washington, 1881. Presented by the Bureau.

Chief of Engineers, U. S. A. Index to Reports of, 1866—1879. Washington, 1881. Presented by the Chief of Engineers.

Colonial History of the State of New Jersey. Documents relating to. Vol. 2, 1687—1703. Newark, 1881.
Presented by the State Librarian.

Commerce and Navigation, U. S. Report of the Chief of Bureau of Statistics for 1880. Presented by the Chief of Bureau.

Commercial Relations of the United States. Report on for 1878.
Presented by the Department of State.

Commercial Relations of the United States with Foreign Countries. Report on, for 1879. Washington, 1880.
Presented by the Department of State.

Compagnie Universelle du Canal maritime de Suez. Bulletin decadaire. Nos. 310—330. Paris. Presented by Prof. J. E. Nourse.

Darwin, C. Vegetable Mould, etc. N. Y., 1882.

Emanuel, H. Diamonds. London, 1867.

Fairmount Park Art Association. Eighth and Ninth Annual Reports. Philadelphia, 1880—1881. Presented by the Association.

Germanischer Lloyd. Internationales Register. Berlin, 1882.
Presented by the Association.

Gillmore, Q. A. Report on Strength of Building Material. Washington, 1874. Presented by Engineer Department.

Gouge, H. A. Ventilation. New York, 1881.

Harvard College Observatory, Thirty-sixth Report of Director of. Cambridge, 1882. Presented by the College.

Ingersoll, E., and H. W. Elliott. Fisheries Industries. Washington, 1881. Presented by Census Bureau.

Internal Revenue. Report of Commissioner, for 1881. Presented by the Commissioner.

Journal de l'Union des Eaux des deux Mers. June—December, 1856. Presented by Prof. J. E. Nourse.

Lewis, Jr., L. Bank of North America, History of. Philadelphia, 1882.

Lobintz, M. Lecture. Paris, 1868. Presented by Prof. J. E. Nourse.

Lunge. Sulphuric Acid. Vol. 3. London, 1880.

Magnetical and Meteorological Observations made at Bombay in 1871—1878. Presented by the Governor.

Mallory Steering and Propelling Screw, Report on. Washington, 1882. Presented by Engineer Department.

Marine and Fisheries Department, Canada.
Annual Reports of the Department for 1879 and 1880.
Fisheries Statements for 1877 to 1880.
List of Lights and Fog Signals, 1879 and 1880.
List of Vessels on Registry Book in 1877.
Reports of Board of Steamboat Inspection, etc., for 1879 and 1880. Presented by the Department.

Message of the President of the United States to Congress. Washington, 1880. Presented by Department of State.

Meteorological Office, Quarterly Weather Report of. January—March, 1876. London. Presented by the Office.

Millers' Journal. Vols. 11, 12 and 14. New York.

Musical and Dramatic Courier. Vol. 1. New York, 1880. Presented by Howard Lockwood, Publisher.

Ministerio de Fomento. Republica Mexicana-Anales. Tomo 5. 1881. Presented by the Minister.

Mortality Statistics. Census of 1850. Washington, 1855.

Navy of United States, Register of Officers of. Washington, 1882. Presented by the Navy Department.

Nichols, W. R. Publications of Massachusetts Institute of Technology. Cambridge, 1882. Presented by the Author.

Paper Trade Journal. Vols. 7 and 8, and Nos. 1—32, Vol. 9. New York. Presented by Howard Lockwood, Publisher.

Paris Universal Exposition, 1878. Reports of United States Commissioners. 5 Vols. Washington, 1880.
Presented by Department of State.

Photographic News. Vols. 1—8. London.

Roscoe and Schorlemmer. Chemistry. Vol. 3. New York, 1882.

Royal Astronomical Society. Monthly Notices. Vols. 8 and 9.
Index to Vols. 1—29. London. Presented by the Society.

Stallo, J. B. Modern Physics. New York, 1882.

State Board of Health of Michigan. Reports for 1879 and 1880.
Presented by the State Board.

Stauffer, D. McN. Shaft Sinking.

Stewart and Tait. Unseen Universe. London.

Strecker, A. Chemistry. New York, 1882.

Swank, J. M. Iron and Steel Production in the United States. Tenth Census. Washington, 1881. Presented by Census Bureau.

Treasury Department United States. Annual Report of the Secretary on the Finances, for 1881. Washington, 1881.
Presented by the Department.

University of Tokio. Calendar of Departments of Law, etc. Tokio, Japan. 1880.
Memoirs of Science Department. Tokio, 1880.
Presented by the Departments.

War Department. Report of Secretary. Vol. 1. Washington, 1879.
Presented by the Secretary.

Watts. Dictionary of Chemistry. Suppl. Pt. 2, Vol. 3. London, 1881.

Wex, G. Decrease of Water in Springs, etc. Washington, 1881.
Presented by Engineer Department.

Wilson, H. A. Compressed Pellets. Philadelphia, 1881.
Presented by Author.

E. Hiltebrand, *Librarian.*

Errata.—*Curves of Efficiency*, February, 1882. On page 91, for "r^{2-n}, r^{3-n}," read r^{-n}, r^{1-n}.

On page 94, lines 12, 23, for "0·3" and "$\frac{1}{2}$," read —0·5; in line 25, read "volume of boiler steam."

④ JOURNAL

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ON THE SEVERAL EFFICIENCIES OF THE STEAM ENGINE, AND ON THE CONDITIONS OF MAXIMUM ECONOMY.

By Robert H. Thurston.

Presented to the American Society of Mechanical Engineers, Philadelphia Meeting, April, 1882.

Section I.—Methods and Principles.

1. The Several Efficiencies of the Steam Engine.

In the design of the Steam Engine, the Mechanical Engineer has frequent occasion to solve certain problems relating to its economical performance, and especially to determine what proportions of engine and boiler are best adapted to give maximum economy of fuel or of money under certain conditions precisely defined in advance. Such problems may usually be solved by the determination of the Ratio of Expansion producing Maximum Economy under the given conditions. The methods proposed by the writer for the solution of these problems form the subject of this paper.

Several problems of this character may be classed together, all of which relate to one or another of the "Several Efficiencies of the Steam Engine," as the writer has called them.

These "Efficiencies" are:

(1) *The Efficiency of Fluid.*—This is measured by the ratio of work done by the working substance to the mechanical equivalent of the heat expended on it. In the perfect engine this efficiency is measured by the quantity $\frac{\tau_1 - \tau_2}{\tau_1}$; the range of temperature worked through, divided by the maximum, initial, absolute temperature of the fluid entering the cylinder of the engine. In real engines, great losses occur by incomplete expansion and by direct transfer of heat from induction to exhaust without production of work.

(2) *The Efficiency of the Machine.*—This is measured by the ratio of the quantity of work transmitted from the engine to the "machinery of transmission" to the work done upon the piston by the working fluid.

(3) In some cases the product of the efficiency of the fluid by the efficiency of the machine is called the *Efficiency of the Engine* or of the System.

(4) *The Efficiency of the Furnace* is the ratio of quantity of heat transferred to the working substance to that developed by the fuel.

(5) The *Total Efficiency of the Apparatus, or of Plant,* as the writer would term it, is the product of these several partial efficiencies, and is the fraction of the total calorific power of fuel which is delivered to the machinery of transmission as mechanical energy.

(6) *The Efficiency of Capital,* or the Commercial Efficiency of Steam Machinery, is measured by the amount of capital employed, or of the total running expenses per unit of a given power required and obtained; *i. e.*, it determines how small a sum will provide a given amount of power and *what size of engine must be selected for the given work.*

Each of the above efficiencies is made a maximum by a set of conditions the determination of which constitutes an important problem in the Science of Engineering. Each must be solved, and in a certain definite order, before the engineer can feel perfectly confident of full success in the application of steam power to any given case. The determination of the efficiency of fluid is included in the problem relating to efficiency of engine, and this and all other efficiencies are included in the last—the Efficiency of Capital—which cannot be exactly determined unless they are first ascertained.

(7) In addition to the above, another problem may present itself to the user of power, although seldom to the designer, or to any one

proposing to purchase a steam engine—the determination of the maximum economy of a given plant; *i. e.*, how the most work may be obtained for a dollar from a given engine already constructed. This is entirely a different problem from (6); its solution leads to very different results, and does not usually, if ever, determine maximum commercial efficiency, as will be seen later. Here, then, the problem relates to what may be called the "*Maximum Commercial Efficiency of a given Plant.*"

(8) It may, finally, be necessary to determine still another question: "*What is the Maximum Amount of Power that can be profitably obtained from a Given Plant?* This is a more commonly familiar problem than the last and of more direct and practical importance in most cases.

2. *Furnace and Boiler Efficiencies.*

The first case which naturally presents itself to the designing engineer, that relating to *Efficiency of Furnace, or of Boiler*, has been frequently studied, and is well understood. To secure maximum efficiency, the engineer must provide for:

(1) Complete combination of fuel and oxygen without excess of air supply.

(2) Rapid and concentrated combustion.

(3) Rapid and general circulation of the heating-gases and of the heated fluid.

(4) Ample area of well-arranged heating surface to transfer heat from the furnace gas to the water.

In the case of a steam boiler, efficiency is a function of area of heating surface and of quantity of fuel burned on the given area of grate surface. Rankine deduces the expression

$$\frac{E}{E'} = \frac{B}{1 + \frac{AF}{S}}$$

in which $\frac{E}{E'}$ is the ratio of water evaporated per pound of fuel to that which would be evaporated were the whole calorific power of the fuel utilized. Then

$$E = \frac{BE'}{1 + \frac{AF}{S}}; \quad S = \frac{FA}{\frac{BE'}{E} - 1};$$

S is the area of heating surface per unit of area of grate and F the

number of pounds of fuel burned per hour per square foot of grate. The constant B is, for bituminous coal, burned in good boilers about 1; A varies from 0·3 with forced draught to 0·5 with chimney draught, probably varying nearly as the square of the weight of air supplied the fuels. Where a forced circulation has been obtained, the writer has found a lower value even than 0·3. In experiments with anthracite coal he has usually obtained a lower value of B than is given above, varying from 0·85 to 0·90.

The engineer in using the above formula usually decides what efficiency he can afford to pay for and then obtains the value of S and thus determines the size and weight of his boiler; he rarely makes $\frac{E}{E'}$ exceed 0·75 and will often find it best to accept a much lower value in order to obtain maximum commercial efficiency. This case should be treated similarly to that relating to the commercial efficiency of engines described hereafter at some length, thus:

It will be found that the maximum commercial efficiency of boiler—*i. e.*, the proportion of heating surface to grate surface or to fuel burned on the grate per hour which gives the required amount of steam at least total expenditure—is determined by the equations,

$$S = A'F\sqrt{R}, \quad \frac{S}{F} = A'\sqrt{R}$$

in which S is the area of heating surface per unit of area of grate; F is the weight of fuel burned on that unit of area; A is a coefficient varying from 0·5 with boilers of quick or forced draught and good circulation to 0·7 with boilers having sluggish draught and a less perfect circulation; R is the quotient obtained by dividing the sum of all annual expenses, dependent on amount of fuel burned, reckoned per pound of fuel and per square foot of grate, by the sum of all the annual expenses per square foot of heating surface, so far as they are dependent upon size and character of boiler; as interest, repairs and depreciation. *E. G.*—For a usual case in marine practice, $A' = 0·5$; $F = 12$; $R = 26$; $S = 30$. For a case of continuous operation of boiler, as in a flour mill, $A' = 0·6$; $F = 10$; $R = 25$; $S = 30$. For certain cases of occasional use, as in a steam yacht, $A' = 0·7$; $F = 12$; $R = 10$; $S = 28$; $A' = 0·6$; $F = 10$; $R = 8$; $S = 17$.

R sometimes becomes as great as 50 in ordinary practice when fuel is expensive.

The proportions of boilers of any given class are seen to be dependent solely upon the quality of fuel burned, and the relation existing between the two classes of expenses—those of operation and those of maintenance.

When the boiler is once constructed and set, it is sometimes found possible to use profitably a larger quantity of steam than it was designed to furnish, and it may become a matter of interest, if not of importance, to determine what amount of steam will give the largest quantity per dollar of total running expense. In such a case the boiler is worked with a more rapid draught, and more fuel is burned on the grate, other conditions affecting efficiency being constant except as dependent upon the quantity, F, which now becomes the independent variable. The total cost of steam now becomes the sum of all expenses, constant and variable, and, calling K the annual cost of all items invariable with variation of quantity of coal burned, and $k = \frac{K}{G}$, this cost divided by area of the grate, it will be found that the "Maximum Commercial Efficiency of Plant," as the writer calls it, will be obtained when

$$F = \sqrt{\frac{k\ S + D\ S^2}{A\ C}}$$

when D is the annual cost per unit of S, as before, of items variable with S; and C is the annual cost, as before, per unit of F, of items variable with F. The boiler may often be profitably forced still further, until the cost of working no longer allows a profit on the steam made and used; but this limit may be reached either within or beyond the value of F, just deduced; it is found, when, if k, C and D measure the cost of constant items of expense per unit of grate area of variable expenses for fuel and for boiler, and M is the *value* of steam, per unit of weight,

$$k\ G + C\ F\ G + D\ G\ S = M\ F\ G\ E'$$

i. e., when the sum of all expenses becomes equal to the total *value* of the steam made. The analysis covering this case will be given in a later paper.

3. *Efficiency of Engine.*

The efficiency of engine has been often studied by authorities accepted as a standard, but almost invariably as a problem in thermodynamids, simply; and the losses of heat occurring in consequence of

the working of steam in a cylinder composed of a good conductor of heat have been left unnoted although frequently the most important of all the expenditures of heat taking place in the engine. Mr. D. K. Clark discovered this phenomenon in 1851 and described it clearly in his papers and late publications. Professor Rankine noted this method of waste and describes the phenomenon fully as early as 1859,* but neither he nor any other writer, Clark excepted, for many years, seems to have realized the extent and importance of this loss in all engines.† Prof. Cotterill alone, of all authors known to the writer, has treated this part of the problem of steam engine efficiency in a manner that is at all practically satisfactory to the engineer.‡

The writer has endeavored in an earlier paper § to show what conditions determine maximum efficiency of fluid and of engine. In a non-conducting cylinder the maximum Efficiency of Fluid would be secured if the ratio of expansion were made nearly equal to the quotient of initial by back pressure; $r^n = \frac{p_1}{p_3} = \frac{p_1}{p_2}$, while the efficiency of engine would be made a maximum when the ratio is made equal to the quotient of initial pressure by the sum of all useless resistance; $r^n = \frac{p_1}{p_b} = \frac{p_1}{p_2}$. When, however, as is always the case in practice, the steam is worked in a metallic cylinder, the best ratio of expansion is made very much smaller, and the efficiency of the engine is greatly reduced by cylinder condensation and reëvaporation, which produce a serious waste of heat. The extent of this modification has been indicated by the writer, and an attempt has been made to determine by simple method based on experiment and observation what are the usually best ratios of expansion and what the least probable quantities of steam and of fuel demanded per hour and per horse-power, at maximum efficiency by the principal standard types of engine.

In a still later paper‖ the writer has exhibited at greater length the differences in the behavior of steam expanding in a non-conducting

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* Steam Engine, etc., § 286; par. 2.

† Proc. Inst. Mech. Engrs., 1852; Railway Machinery, 1855; Handbook for Mech. Engrs , 1877.

‡ The Steam Engine considered as a Heat Engine; J. H. Cotterill, London and New York, 1878

§ On the Ratio of Expansion at Maximum Efficiency.—*Trans. Am. Soc. Mech. Engrs.*, 1881.—*Journal Franklin Institute*, May, 1881.

‖ On the behavior of Steam in the Steam Engine, etc.—*Jour. Frank. Inst.*, Feb., 1881.

vessel, and in the metal cylinder of the steam engine, and has shown how to determine and construct true "Curves of Efficiency" for actual engines, exhibiting the charater of this newly discovered curve, and its functions. It was shown that the total loss of efficiency of work, or of pressure, due to cylinder condensation, may be allowed for by taking for its value the expression $a\ r^m$, in which a is constant dependent upon the state of the steam before expansion, r is the rate of expansion, and ^{m} is an exponent dependent upon the method of variation of the proportions of the mixture of steam and water as expansion progresses.

The useful work per stroke is a maximum, and the ratio of expansion at maximum efficiency of engine is found when the latter is of such value as to satisfy the equation

$$r^{-n} - a\ r^{m-n} = \frac{p_b}{p_1}, \text{ nearly,}$$

and when, if c is the "cut-off"

$$c^n - a\ c^{n-m} = \frac{p_b}{p_1}, \text{ nearly.}$$

The value of the constant a varies from 0·1 to 0·2, in good engines, according to quality of steam supplied, and ^{m} may be taken at 0 in the best cases of well designed compound engines, and as rising to 0·5 in unjacketed single cylinder engines; n is the exponent in the equation of the expansion line.

The probable minimum expenditure of steam per hour and per horse-power were also given as follows in the first of this series of papers:

Probable Minimum Weights of Steam per Hour per Horse-power.

r_e	W Pounds.	W_m Kilos.	r	W Pounds.	W_m Kilos.	r_e	W Pounds.	W_m Kilos.
3	32	15	8	20	9	13	17	8
4	27	12	9	19	9	14	16	7
5	25	11	10	19	9	16	16	7
6	22	11	11	18	9	20	15	7
7	20	9	12	17	8	25	15	7

Studying these modifying conditions as observed in practice, the best rates of expansion for maximum duty r_e^1, for several well-known and typical classes of engines are taken by the writer thus:

Probable Terminal Pressures and Rates of Expansion at Maximum Efficiency.

Case.	Initial Pressures. *Absolute.*		Speed of Piston.		SINGLE CYLINDERS. Class I.—Non-condensing.						SINGLE CYLINDERS. Class II.—Condensing.						COMPOUND (N=2) CONDENSING. Class III.								
					Unjacketed.			Jacketed.			Unjacketed.			Jacketed.			Sides jacketed.			Heads and sides jacketed.			Heads and sides jacketed with efficient superheating.		
					$p_t=p_v$		r_e^1	$p_t=p_v$		r_e^1	$p_t=p_v=p_e$		r_e^1	$p_t=p_v=p_e$		r_e^1	$p_t=p_v=p_e$		r_e^1	$p_t=p_v=p_e$		r_e^1	$p_t=p_v=p_b+p_f$		r_e^1
	P_1	P_m	V	V_m	Lbs. on sq. in.	Kilos on sq. cm.		Lbs. on sq. in.	Kilos on sq. cm.		Lbs. on sq. in.	Kilos on sq. cm.		Lbs. on sq. in.	Kilos on sq. cm.		Lbs. on sq. in.	Kilos on sq. cm.		Lbs. on sq. in.	Kilos on sq. cm.		Lbs. on sq. in.	Kilos on sq. cm.	
I.	40	2·8	400	122	20	1·4	2·0	20	1·4	2·0	16	1·1	2·5	13	·9	3·0	9	·6	4·5	7½	·5	5	7½	·5	5
			625	185	20	1·4	2·0	20	1·4	2·0	13	·9	3·0	13	·9	3·0	9	.6	4·5	7½	·5	5	7½	·5	5
II.	60	4·2	400	122	20	1·4	3·0	20	1·4	3·0	20	1·4	3·0	15	1·1	4·0	11	·8	5·5	8	·6	7·5	7½	·5	8
			625	185	20	1·4	3·0	20	1·4	3·0	15	1·1	4·0	15	1·1	4·0	11	·8	5·5	8	·6	7·5	7½	·5	8
III.	80	5·6	400	122	23	1·6	3·5	20	1·4	4·0	23	1·6	3·5	18	1·3	4·5	13	·9	6·5	9	·6	9	7½	·5	11
			625	185	20	1·4	4·0	20	1·4	4·0	18	1·3	4·5	18	1·3	4·5	13	.9	6·5	9	·6	9	7½	·5	11
IV.	100	7·0	400	122	25	1·8	4·0	20	1·4	5·0	25	1·8	5	20	1·4	5·0	14	1·1	7·0	10	·7	10	7½	·5	13
			625	185	20	1·4	5·0	20	1·4	5·0	20	1·4	5	20	1·4	5·0	14	1·1	7·0	10	·7	10	7½	·5	13
V.	120	8·4	400	122	27	1·9	4.5	22	1·5	5·5	27	1·9	4·5	22	1·5	5·5	16	1·1	7·5	11	·8	10·5	7½	·5	17
			625	185	22	1·5	5·5	22	1·5	5·5	22	1·5	5·5	22	1·8	5·5	16	1·1	6·5	11	·8	10·5	7½	·5	17
VI.	150	10·5	400	122	30	2·1	5·0	25	1·8	6	30	2·1	5·0	25	1·3	6·0	18	1·3	8·5	12·5	·9	12	7½	·5	20
			625	185	25	1·8	6·0	25	1·8	6	25	1·8	6·0	25	1·1	6·0	18	1·3	8·5	12·5	·9	12	7½	·5	20
VII.	200	14.1	400	122	36	2·6	5·5	29	2·1	7	36	2·5	5·5	29	2·1	7·0	20	1·4	10·0	14	1·0	14	7½	·5	27
			625	185	29	2·1	7·0	20	2·1	7	29	2·1	7·0	29	2·1	7·0	20	1·4	10·0	14	1·0	14	7½	·5	27

The terminal pressure $p_t=p_v$ is taken as equal to p_3+p_f the sum of back pressure and frictional resistance in non-condensing engines with low steam, and in highly superheated steam engines.

Deduct 14·7 lbs. per sq. in. = 1 kg. per sq. cm. to obtain gauge pressures. Hyperbolic expansion is here assumed.

P_1 P_m are pressures in British and Metric measures, V_1 V_m are velocities in the same measure.

Taking the probable minimum expenditure of coal per hour and per horse-power at *one-ninth* the weight of steam demanded, we get, at the ratio of expansion giving a minimum cost of steam, the following:

Probable Minimum Weights of Coal per Horse-power per Hour.

r_e	W'' Pounds.	W''_m Kilos.	r_e	W'' Pounds.	W''_m Kilos.	r_e	W'' Pounds.	W''_m Kilos.
3	3·5	1·6	8	2·2	1·0	13	1·9	0·9
4	3·0	1·4	9	2·1	1·0	14	1·8	0·8
5	2·8	1·3	10	2·1	1·0	16	1·8	0·8
6	2·3	1·1	11	2·0	0·9	20	1·7	0·8
7	2·2	1·1	12	1·9	0·9	25	1·7	0.8

For cases in which the boiler gives an evaporation of ten pounds of water per pound of coal we may get ten per cent. better figures.

The Efficiency of the Apparatus is the product of efficiency of furnace and boiler, the efficiency of engine and the efficiency of mechanism of transmission. It is made a maximum when each of its factors is a maximum.

4. Efficiency of Capital.

The Efficiency of Capital, Case 6, is the most interesting of this series of problems of maximum efficiency, and its solution, by a practically correct method giving reliable results accordant with experience has been, by some engineers, regarded as one of the most important of problems now demanding the attention of the engineer. It is this problem which is proposed as the principal subject of the present paper.* In studying the efficiency of capital, it is first necessary to consider the elements of cost of power. The problem may be stated thus: *Given* the quantity of power required, to determine what ratio of expansion and what size of engine will give that power at minimum cost.

To solve this problem the engineer must know the cost of the engines, boilers and appurtenances and all items of running expense.

* This problem was first enunciated by Rankine, and solved for the case of the non-conducting cylinder.—*Vide Phil. Mag.*, 1854; *Miscell. Papers*, p. 295.

Then making the sum of both items of variable annual expense—those variable with size of engine and those variable with quantity of steam demanded—a minimum, the sum of these items and of all invariable expenses, *i. e.*, of the total running expense, becomes a minimum, and the problem is solved. A knowledge of these conditions and of all other expenses, constant as well as variable, is also essential to the treatment of Case 7, which may be thus stated:*

Given the size, power and all items of cost, and running expenses of a known plant of steam machinery, to determine what method of working the steam, *i. e.*, what ratio of expansion will give most work for a dollar of total expense of operation.

Since the economy of fuel and steam demands the use of a large engine, working steam with a considerable expansion and gives reduced size and weight of boiler, it is evident that the first of these two problems is to be solved by determining what proportion of engine and boiler will be cheapest when summed up at the end of the life of the plant; this is settled when the ratio of expansion at maximum commercial efficiency is known, since the best size of engine and boiler is then fixed. The work may be done either by a large engine and a small boiler, or by a smaller engine supplied with more steam by larger boilers.

The second problem—Case 7—is solved by determining what degree of expansion will give most power from an engine and boiler already installed, at least cost per horse-power. The first problem contains, as elements, all items of cost variable with change of proportions of engines and boilers capable of doing the same given quantity of work. The second problem considers every item of expense, and the amount of power is a variable quantity. Both problems require the study of the costs of steam power and the determination of the way in which each is related to total expense and the manner in which each varies with variation of the variable quantities in either case.

If, therefore, we have given a certain annual invariable expense of operation, certain additional expenses variable with size of engine, and therefore with the ratio of expansion adopted, and certain other additional expenses variable with quantity of steam demanded and with size of boiler needed, and thus also dependent upon the ratio of

* First treated, so far as the writer is aware, by Messrs. Wolff and Denton, who solved it for the ideal case.—*Trans. Am. Society Mech. Engrs.*, 1881; *American Engineer*, 1881.

expansion at which that steam is used, we may call the two latter quantities, respectively, $f^{i}(r)$ and $f^{ii}(r)$ while the constant part may be called C. Then the total annual expense is $f^{i}(r)+f^{ii}(r)+C$, which is a minimum when the variable part, $f^{i}(r)+f^{ii}(r)=f(r)$ is a minimum, and this is a minimum when its ratio to work done, $F(r)$, is a minimum, *i. e.*, when $\frac{f(r)}{F(r)}$ is a minimum, or $d\,\frac{f(r)}{F(r)} \div dr=0$. The value of r which satisfies this condition gives Maximum Commercial Efficiency.

The determination of the value of r which makes $\frac{f(r)+C}{F(r)}$ a minimum, gives the solution of Case 7.

Case 8 is solved by determining at what ratio of expansion the cost of power becomes equal to the market value of the power, less a paying profit.

The Annual Cost of Steam Power consists:

(1) Of certain expenses, which, in any given case, are usually invariable, whether the work is done by a large engine with high ratio of expansion and small boilers, or with a smaller engine working at a low rate of expansion and with larger boilers. These are usually: rent of building or interest on cost, taxes, repairs, etc., etc., of structure and location, the engineer's salary and sometimes all or part of the fireman's or stoker's, also sundry minor expenses or a part of each of other expenses, which as a whole are variable. Both of the latter classes may usually be neglected in solving the problems here first considered.

(2) The interest on first cost of engine in place, the cost of repairs, and a sum which measures the depreciation in value of the machine due to its natural wear, or to its decreasing value in presence of changes that finally compel the substitution for it of an improved engine. Oil, waste and other engineer's stores fall under this head. These items are variable with size and style of engine.

(3) The expenses of supplying the engine with steam. These are:

(*a*) The cost on fuel account of the steam supplied and which includes also the cost of steam condensed *en route* to the engines and wasted by cylinder condensation and leakage, as well as that actually utilized. This total quantity of steam greatly exceeds that actually used in the production of power by simple transformation of heat

energy. This item varies with the efficiency of engine and size of boiler demanded.

(*b*) The account of interest on cost of boilers in place and of their appurtenances, rent of boiler-room, depreciation, repairs and insurance; which latter account is wholly chargeable to boilers. This is also variable with size of boilers.

(*c*) Cost of attendance in excess of the costs included in the constant quantity in item (1) and variable with size of boiler or quantity of steam demanded.

The salary of the engineer is usually not chargeable to either engine or boiler; his position is one of supervision over the whole apparatus, and a good engineer usually keeps the closest watch over the boilers. The engine can usually be trusted, much of the time, to take care of itself. With small engines, the engineer is also the fireman. With large engines, the number of regular firemen, or, at least the number in excess of one attendant may be taken as proportional to the quantity of steam demanded when working at ordinary power, and with very large marine engines, the same remark will apply to engine-room attendance.

In recapitulation:

(1) In working up this account, it will be most convenient, as will be presently seen, to refer all costs to volume of cylinder and to so express variable quantities that they may enter our equations in terms of the ratio of expansion, which ratio is to be taken as hereafter shown, as an independent variable upon which all other variable quantities are made dependent. We will enter all constant quantities as so many dollars of *annual* expense; the total, invariable expense will then be A, where A includes all such expenses, whether chargeable to the engines or boilers, or to both.

(2) The cost of an engine varies according to no definite rule, and differs greatly with type of engine, kind of valve gear, character of work and value of material and labor, both at the manufactory and at the place of installation. With certain standard forms of engine, however, it is found that the cost to the builder may be reckoned as very nearly proportional to volume of steam-cylinder, and his prices may be fixed on that basis. The cost of transportation, other things being equal, may often be similarly estimated, as may expenditures for repairs, engineer's supplies, etc., although these items are less exactly determinable.

It is here assumed that interest on cost of engine in place, depreciation, repairs and all other expenses variable with size of engine, are to be reckoned per cubic foot of cylinder. This method is, in the opinion of the writer, more nearly correct than any other system of charging to this account that he has considered, and its probable error will be certainly unimportant for the small range met with in the usual case here studied.

(3) The cost of steam supplied to the engine, exclusive of the constant quantity entered in (1) may be safely reckoned as a certain number of dollars per pound or per cubic foot of steam worked in the cylinder.

The weight of steam supplied for the performance of work—when the weight per cubic foot of steam at the given pressure, p, is w, and its volume is $v_1 = v_2 \div r$, where r is the "real" ratio of expansion, is $w\, v_1 = \frac{w\, v_2}{r}$; its cost per cubic foot of steam cylinder is $\frac{C\, w\, v_1}{v_2} = \frac{C\, w}{r}$, and its total cost per year is $2\, R\, C\, w\, v_1 = 2\, R\, C\, \frac{w\, v_2}{r}$, where R is the number of revolutions made by the engine per annum.

To this weight is to be added steam wasted by cylinder condensation, leakage and by conduction and radiation from engine and boiler. This last quantity varies greatly with kind of engine, speed of piston and other circumstances more or less under control of the builder or engineer. It sometimes even amounts to several times as much as the steam actually utilized.

It may be allowed for by multiplying the last item by a factor greater than unity.

5. *Theory of the Efficiencies of the Perfect Ideal Steam Engine.*

When, as is perhaps sometimes allowable, if treating of the best of modern engines, the variation of cylinder condensation with variation of the ratio of expansion may be neglected, the "EQUATION OF IDEAL STEAM ENGINE EFFICIENCIES," as the writer would call it, may be written:

$$V = \frac{1}{E^{\text{iii}}} = \frac{A\, r\, v_1 + B\, v_1}{2\, R\, W_n} = \frac{A + B\, r^{-1}}{2\, R \left(p_1 \frac{n r^{-1} - r^{-n}}{n-1} - p_b \right)}$$

Where V is the counter efficiency, and E^{iii} is the ratio of work done

to variable costs, and therefore in the sense adopted here, the efficiency. This becomes a minimum, and the best ratio of expansion is obtained when, r being made the independent variable,

$$A\,p_1 \frac{n-n\,r^{1-n}}{n-1} - B\,(p_1 r^{-n} - p_b) = 0\,;\; r^{-n} - M\,\frac{n-n\,r^{1-n}}{n-1} = \frac{p_b}{p_1}$$

Here r has become r_e[iii]. In these equations A is the total annual variable charge per cubic foot of cylinder on engine account, B is the annual cost of steam per cubic foot *filled* each stroke, and is measured by $2\,R\,w\,C$, when R is the number of revolutions of engine *per annum*, w the weight of a cubic foot of steam at the pressure p_1, and C its cost per pound, including all running expenses, in the boiler room, and $M = \frac{A}{B}$.

More explicitly: since this problem demands minimum cost of a known power and the Ratio of Expansion at Maximum Commercial Efficiency, we have

$$p_1 v_1 \frac{n - r^{1-n}}{n-1} - p_b r v_1 = \text{Constant} = W.$$

The variable cost will be, as before,

$$P = A r v_1 + B v_1,$$

which is to be a minimum. But from the equation of condition, above,

$$v_1 = \frac{W}{p_1 \frac{n - r^{1-n}}{n-1} - p_b r}.$$

Thence

$$u = \frac{M + r^{-1}}{n r^{-1} - r^{-n} - \frac{p_b}{p_1}(n-1)}\,;$$

and the minimum is found, as above, when $\frac{du}{dr} = 0$; *i. e.*, when

$$r^{-n} - M\,\frac{n - n r^{1-n}}{n-1} = \frac{p_b}{p_1}.$$

The construction of the equation shows that, under the assumed conditions, this ratio of maximum commercial economy is not dependent on the size of engine; but small engines have a higher value of p_b than large engines, as they are usually more subject to cylinder condensation, and have greater back pressure and friction. They there-

fore require to be worked with somewhat less expansion than large engines.

Thus the solution of the problem determining the ratio of expansion r_e^{iii} at "Maximum Commercial Efficiency," or Efficiency of Capital, fixes that size of engine which, doing the required work, will do it at least cost. The sum of all variable expenses being here made a minimum, the total running expense, which includes all variable charges, also becomes the least possible, and the given work is done at least total annual cost.

To find the ratio of expansion at which the given engine will give the largest amount of work for the dollar, *i. e.*, to determine the "Ratio of Expansion r_e^{iv} at Maximum Efficiency of a Given Plant," we may use this same general equation. In this case, the size of the engine being fixed, the annual "cost of engine" becomes constant, and we write the equation in precisely the same form as before.

$$V = \frac{1}{E^{iv}} = \frac{A_1\, r\, v_1 + B\, v_1}{2\, R\, W_n}$$

making the symbol A_1 cover all annual expenses of the engine room, estimated per cubic foot of cylinder, including all the *constant* charges of attendance in the boiler room as well, while B only includes costs variable with the steam supply; V thus measures the ratio of total annual expenses of operation to work done. We thus obtain such a ratio of expansion that

$$r^{-n} - N\,\frac{n - n\,r^{1-n}}{n-1} = \frac{p_b}{p_1}$$

when N is the ratio of the total expenses classed with engine cost to the "cost of full steam," as already taken, and r has become r_e^{iv}.

Again: making A and N equal zero in the general equation, and making p_b the sum of all useless resistances

$$r^{-n} = \frac{p_b}{p_1}$$

and $r = r_e^{ii}$, the ratio of expansion at "Maximum Efficiency of Engine."

Similarly, if p_3 is the back pressure in the steam cylinder

$$r^{-n} = \frac{p_3}{p_1}$$

and we have the ratio of expansion at "maximum efficiency of fluid," $r = r_e^{i}$.

In each case the expression obtained is derived, it will be noted, by making r the independent variable, and is independent of the actual size of the engine. Thus we determine, in each case, the ratio of efficiency which is correct under the assumed conditions for all engines of the class upon which our estimates are based.

We thus are able to *tabulate* the proper size of engine for assumed quantities of work, and the powers at which each engine, once set, will work with maximum efficiency, commercial or other, if the power can be utilized. Finally, comparing costs, it can be determined in any known case just when a change of engine will be financially advisable. But the above simple and beautiful method of treatment cannot be applied where cylinder condensation becomes a serious item; in fact, therefore, it is comparatively valueless for nearly all cases which come up in engineering practice.

A comparison of the quantities of steam demanded to supply an engine thermodynamically "perfect" with the actual quantities required by even the best engines exhibits so wide a difference that it becomes obvious that the determination of the efficiency of an engine and the solution of the questions involving those of expenditure of heat are not problems in thermodynamics simply. The mathematical theory of the steam engine is not yet in so satisfactory a state, and cannot be until the correct theory of this transfer of waste heat can be introduced into it—that the engineer can often use it in every-day office-work with much confidence, unless checked by direct experiment. Even where algebraic analysis is probably capable of giving approximate results, few engineers will attempt to use it. For the latter case, however, Rankine's graphical treatment of the problem here studied is conveniently applicable, and by its use the engineer may easily solve such problems by a simple construction on his drawing board.

6. *Rankine's Diagram of Efficiency.*

In illustration: Suppose an engine, of one cubic foot capacity, in operation, expanding steam adiabatically, its cylinder and piston being perfectly impervious to heat, and having an "adjustable" expansion gear. When following full stroke it uses one cubic foot of steam per stroke, at initial pressure; when "cutting off" at half stroke, one-half cubic foot, and at a cut-off of one quarter, one-fourth of a foot, are used. The quantity used is always inversely as the ratio of expansion. To determine the best ratio of expansion: Construct a

curve, $O\ A$, of which the abscissas along $O\ X$ are proportional to the amount of steam used, while the ordinates parallel to $O\ Y$ are proportional to the absolute mean pressure for that degree of expansion, and therefore to the "total work" done by the steam so measured off. Drawing a line, $B\ C$, parallel to the base, and at a height proportional to the back pressure in the engine cylinder, the ordinates measured from any point in the curve down to this line will measure the

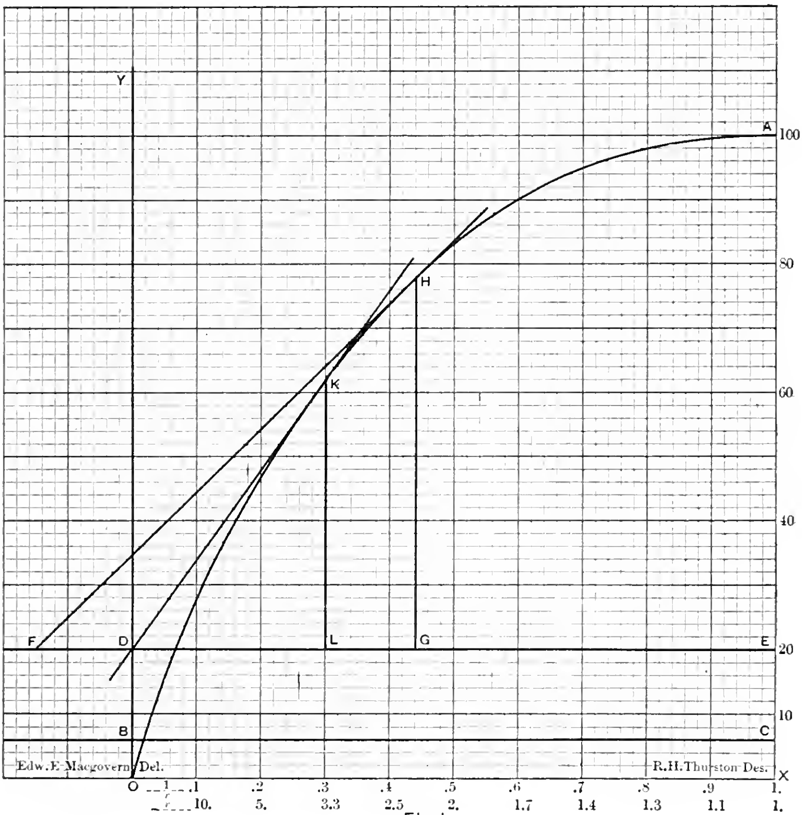


Fig. I.

"effective pressure" shown by the indicator, and will be proportional to the "indicated power" of the engine. Again: Drawing a line, $D\ E$, at the height measuring the sum of all useless resistances, the "net" or "dynamometric" power of the engine, as transmitted to the machinery of transmission, is measured by this line. Finally, extending this second line toward the left, and measuring off upon it a dis-

tance proportional to the cost of operation, so far as it varies with changes in plant, and measured on the same scale as is used in laying off the base line in terms of cost of steam, the sum of the two costs, *G F*, measures the total variable expense of obtaining the power, while the height of ordinate *G H*, measured from the last drawn line, is proportional to the amount of power obtained. For any one point, *F*, the straight line *F H*, drawn just tangent to the curve, touches the latter at a point marking the ratio of expansion at maximum commercial economy, or if drawn from the axis *O Y*, as *D K*, identifies the ratio for maximum "efficiency" of engine, as that term is technically applied.

This simple construction is correct and exact only when cylinder condensation may be neglected. It has been applied by Rankine to the case of the Cornish Engine, which—because of its effective steam jacketing, singular steam distribution and the peculiar rapidity with which the piston, on the "in-door" stroke, jumps from one end of the cylinder to the other—is usually less affected by that most serious of losses, than is almost any other known form of engine. For other forms of engine this construction leads to results that are often, as will be seen presently, widely inaccurate. It has become perfectly obvious that any method to be accurate and reliable must take account of *all* losses of heat of large amount, and must distinguish between efficient and inefficient classes of heat engines.

7. *Theory of Efficiencies of Real Engines.*

The direct process of analytical treatment of this General Problem for Real Engines, as adopted by the writer, is the following: Let it be known what style of engine is to be adopted for any case and what kind of boilers and attachments are to be used in supplying steam; let the costs of attendance and all other expenses be ascertainable. Then, to adopt Rankine's terms, determine *A*, the annual variable "cost of engine" of the selected type, per cubic foot of steam cylinder, and *B*, the annual variable "cost of boiler," per cubic foot of steam cylinder supplied without expansion and without allowance for cylinder condensation or leakage; ascertain all other costs, invariable with change of size of either engine or boiler within the range of the problem, and call their total *C*.

The "cost of engine" will be $A\ v_2 = A\ r\ v_1$; the "cost of boiler" will be $B\ v_1$ and the constant charges C. Make $\frac{A}{B} = M$.

The work done per stroke may be called W_n, and work per annum becomes $2 R W_n$.

The ratio of the total of annual variable costs of power to work done by the engine is:

$$u = \frac{A\ r\ v_1 + B\ v_1}{2\ R\ W_n} = \frac{A\ v_2 + B\ v_2 r^{-1}}{2\ R\ W_n}$$

which is a minimum when $\frac{M + r^{-1}}{W_n}$ is a minimum.

This value of W_n may be obtained by multiplying the value of W_n for adiabatic expansion, such as would be obtained in a non-conducting cylinder by a factor variable with the ratio of expansion, as has been shown in the preceding page, which shall measure the ratio of actual work done in the metal cylinder to that done in adiabatic expansion. Or thus:

Let b represent the proportion of steam present in the working fluid when $R = 1$, as determined by the amount of cylinder condensation, let r^q represent the rate of variation of losses with increase of the ratio of expansion, and let n be the index for the actual expansion line of the mixture, to be determined, if possible, by experiment.

Then we shall have: $W_n = 2\ R\ b\ p_1\ v_2 \dfrac{n\ r^{-1} - r^{-n}}{n - 1}\ r^q - p_b\ v_2.$

The "GENERAL EQUATION OF ALL STEAM ENGINE EFFICIENCIES," therefore, is

$$V = \frac{1}{E^{iii}} = \frac{A\ v_2 + B\ v_2\ r^{-1}}{2 R \left(b\ p_1\ v_2 \dfrac{n\ r^{-1} - r^{-n}}{n - 1}\ r^q - p_b\ v_2 \right)} \qquad \text{(A)}$$

which becomes a minimum and makes the *Commercial Efficiency* of an engine doing the required work a maximum when, to obtain r_e^{iii}, we have made

$$r^q + \frac{q}{M\ (q - 1)}\ r^{q-1} - \frac{q - n}{n(q - 1)}\ r^{q-n+1} - \frac{q - n + 1}{Mn(q - 1)}\ r^{q-n} = \frac{n - 1}{Mnb(q - 1)}\ \frac{p_b}{p_1} \qquad \text{(B)}$$

When the ratio of expansion, r_e^{iv}, at "*Maximum Efficiency of Fixed Plant*" is required, Av_2 is constant and we may make

$\dfrac{A + \dfrac{C}{r_2}}{B} = N$ and the equation of *Efficiency of Plant*

$$V = \frac{1}{E^{\text{iv}}} = \frac{N + r^{-1}}{2B^{-1}R_e^1\left(b\bar{p}_1 v_2 \dfrac{nr^{-1} - r^{-n}}{n-1} r^q - p_b v_2\right)} \qquad \text{(C)}$$

gives, similarly, for r^{iv} and a maximum,

$$r^q + \frac{q}{N(q-1)} r^{q-1} - \frac{q-n}{n(q-1)} r^{q-n+1} - \frac{q-n+1}{Nn(q-1)} r^{q-n} = \frac{n-1}{Nnb(q-1)} \frac{p_b}{p_1} \qquad \text{(D)}$$

To obtain r_e^{ii} for *Maximum Efficiency of Engine,* we make $N = 0$ and have

$$\frac{q}{q-1} r^{q-1} - \frac{q-n+1}{n(q-1)} r^{q-n} = \frac{n-1}{nb(q-1)} \frac{p_b}{p_1} \qquad \text{(E)}$$

and to obtain *Maximum Efficiency of Fluid,* p_b becomes p_3 and

$$\frac{q}{q-1} r^{q-1} - \frac{q-n+1}{n(q-1)} r^{q-n} = \frac{n-1}{nb(q-1)} \frac{p_3}{p_1} \qquad \text{(F)}$$

in which r_e^{i} satisfies the equation.

When $b = 1$ and $q = 0$, we have the *ideal* case considered in § 5 and the equation (B) for r_e^{iii} becomes, as before, for the perfect engine:

$$r^{-n} - M\frac{n - nr_1^{-n}}{n-1} = \frac{p_b}{p_1} \qquad \text{(G)}$$

for Maximum Commercial Efficiency; and we again obtain for Maximum Economy of a Given Plant, for r_e^{iv},

$$r^{-n} - N\frac{n - nr^{1-n}}{n-1} = \frac{p_b}{p_1} \qquad \text{(H)}$$

For Maximum Efficiency of Engine, we again get a value of r_e^{ii}, such that

$$r^{-n} = \frac{p_b}{p_1} \qquad \text{(I)}$$

and finally for Maximum Efficiency of Fluid we find a value of r_e^{i} such that

$$r^{-n} = \frac{p_3}{p_1} \qquad \text{(J)}$$

precisely as already stated in § 5.

The quantities of steam and of fuel used per hour and per horse-power in the non-conducting cylinder with and without expansion, and in the metal cylinder, with and without expansion, are as

$$1 : \frac{p_1}{p_m r} \text{ and } \frac{1}{b r^{-q}} : \frac{p_1}{b p_m r^{q+1}}.$$

In general, where the Equation of the Curve of Efficiency is given, we shall have at Maximum Efficiency of Fluid

$$\frac{dy}{dx} = \frac{p_m - p_3}{p_1} b\, r^{q+1};$$

at Maximum Efficiency of Engine,

$$\frac{dy}{dx} = \frac{p_m - p_b}{p_1} b r^{q+1};$$

at Maximum Efficiency of Plant,

$$\frac{dy}{dx} = \frac{p_m - p_b}{1 + b r^{q+1} N} \frac{b r^{q+1}}{p_1},$$

and at Maximum Efficiency of Capital,

$$\frac{dy}{dx} = \frac{p_m - p_b}{1 + M b r^{q+1}} \frac{b r^{q+1}}{p_1};$$

for cases met with in practice; while the purely thermo-dynamic treatment gives

$$\frac{dy}{dx} = \frac{p_m - p_3}{p_1} r; \quad \frac{dy}{dx} = \frac{p_m - p_b}{p_1} r;$$

$$\frac{dy}{dx} = \frac{(p_m - p_b) r}{p_1 (1 + N r)}; \quad \frac{dy}{dx} = \frac{(p_m - p_b) r}{p_1 (1 + M r)}$$

for these several cases for the perfect engine.

For the *ideal* case, x and y being the co-ordinates, the equation of the Curve of Efficiency gives

$$\frac{y}{x} = \frac{p_m}{p_1} \div \frac{1}{r} = \frac{n - r^{1-n}}{n - 1};$$

for the real engine,

$$\frac{y}{x} = \frac{p_m}{p_1} \div \frac{1}{b r^{q+1}} = b^2 r^{2q} \frac{n - r^{1-n}}{n - 1}.$$

It will be remembered that ordinates represent the work done by the quantities of steam measured by the corresponding abscissas.

The constants in these formulas should be carefully determined, if possible, by experiment on the class of engine to be designed; but, in

the absence of better data, are taken by the writer, when designing, as follows, for good practice:

		b	q	n
I	Cylinders jacketed, steam superheated at boiler,	0·90	0·	1·06
II	Cylinders jacketed, steam saturated, but dry at boiler, ...	0·85	—0·25	1·06
III	Cylinders unjacketed, steam saturated, but dry at boiler, . . .	0·85	—0·3	0·98
IV	Cylinders unjacketed, steam wet, .	0·80	—0·5	0·95

n is the exponent of the actual probable curve.

Case I is illustrated by the best work yet done by Corliss, Leavitt and Cowper. The value of b is obtained by comparing the actual results of test with the figures for the perfect engine to determine the waste; that of n is obtained by consideration of the fact that in these engines, when effectively jacketed, the steam is retained just dry and saturated during the stroke, and q is taken to be 0, since the rate of transfer of heat to exhaust is nearly constant for such engines so far as known and is of minimum amount. The second case is obtained by examining scattered records of somewhat less efficient engines. The values of b and q for III are obtained by studying the performance of good unjacketed engines; while the last, IV, came originally from the results of test of the U. S. Steamer *Michigan*, with an allowance of ten per cent. for the unrecorded waste concealed by re-evaporation.

8. *Curve of Efficiency for Real Engines.*

The correct curve for the diagram, as has been seen, is neither that due adiabatic nor that given by isothermal expansion, nor is it any known intermediate curve; it has not yet been expressed by any exact equation.* It is never the curve of mean pressures, obtained on the assumption of any yet classified method of expansion and rarely approximates to either of the ideal engine curves. It is very variable in location, in form and in dimensions and, as yet, can only be determined by experiment.

In the diagram above given, it is thus evident, the quantities of steam laid down in mathematical progression on the base line cannot

* An inspection of these curves would indicate that the equation, $y = ae^{-b^c r^d}$, may be more exact than the more manageable forms used by the writer. The general character of these curves was first pointed out by him in debate at the meeting of the Am. Soc. Mech. Engrs., May, 1881.

now correspond with the ratios of expansion there taken; since in actual engines those values are not in exact, or in constant, inverse proportion. The quantity of steam drawn from the boiler is not measured by the volume of cylinder open to steam up to the point of cut-off; nor is the mean pressure obtained with any given weight of steam drawn from the boiler at each stroke, even approximately, equal to that given by adiabatic expansion in a non-conducting cylinder. Both these causes operate to depress and flatten the Curve of Efficiency on the diagram, and thus often to reduce the ratio of economical expansion far below that predicted when the former and impossible conditions were assumed. The vertical scale of pressures and the horizontal scale of ratios of expansion have become altered in relative magnitude, and the latter becomes for usual cases a variable scale.

To obtain a solution of the actual problem as presented daily to the designing engineer, a new method of procedure must be adopted. The writer proposes the following as simple in principle, easy of application and especially as giving, from the use of experimentally derived data, results which may be received with confidence and used for any engine falling into the class of typical cases studied.

9. Thurston's Diagram and Curve of Efficiency.

It has become evident that the best ratio of expansion or proper "point of cut-off" for any actual case is determined, not by the percentage of loss sustained at that point simply, or, by the cylinder condensation there taking place, but by the *method of variation* of such loss, not only at that point but all along the curve of efficiency and at other ratios of expansion, for, in the metallic cylinder, the proportion of the water present in the working fluid is constantly varying with change of volume and the loss of pressure and of work is constantly and proportionally varying, producing a curve of efficiency differing greatly in character, form and location from that given by a non-conducting cylinder.

This "Curve of Efficiency," as discovered by the writer and first described in the paper already referred to, is therefore a curve of peculiar character and essentially different from the line of mean pressures used by Rankine. It is obtained thus:

Assume for the unit of measure so much steam as is drawn from the boiler at one stroke of piston, without expansion, draw OX and divide it as unity of volume or of weight into a scale of equal frac-

tional parts which are to be laid down on both sides of O. Erect at X a perpendicular, XAB, and divide it into any convenient number, say 100, of equal parts. Were there no condensation, the fluid being worked in a vessel of non-conducting material, instead of an iron steam-cylinder, the mean pressure at full stroke and the work done per cubic foot or per pound of boiler steam would be measured by XB, and the curve of mean total pressures or of steam used per "total" horse-power per hour would be OWB.

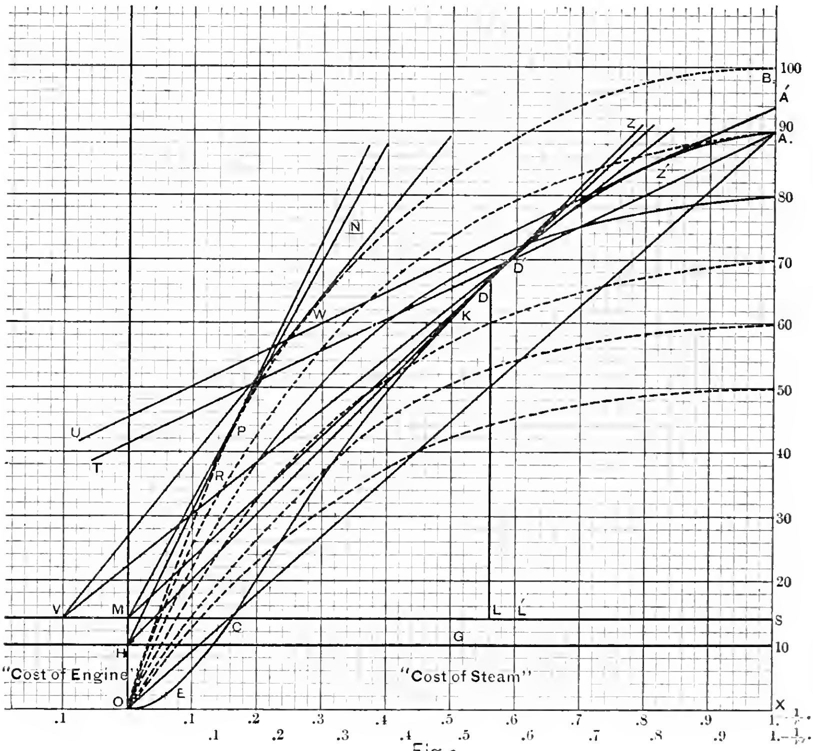


Fig. 2.

Condensation reduces the work at full stroke and it is actually measured by XA. Were the condensation in constant proportion for all values of the real ratio of expansion, the ordinates of the true curve would be proportional to those of OB, and the values of $\frac{1}{r}$ would remain proportional to the expenditure of steam as in adiabatic expansion. But the amount of condensation usually increases,

and often very rapidly, with increasing expansion and at one-half, one-quarter or one-eighth cut-off, more, and sometimes much more, than one-half, one-quarter or one-eighth as much steam is used as at full stroke. The scale of ratios, $\frac{1}{r}$ is thus not only shifted but is made a scale of unequal parts, of which the successive values must be located by determining the amount of steam used at each point of cut-off, and placing the value $\frac{1}{r}$ opposite the value of the corresponding amount of steam expended, as has been done in Fig. 2.

It may be remarked here that if, as is sometimes nearly true, the losses by condensation and leakage, or both, are so great as to annul the benefit derived from expansion, the curve flattens down to a straight line, OA. In every engine a point is reached by increasing r at which the amount of steam used per hour per total horse-power is as great as at full stroke; in every case, therefore, the true curve crosses the line OA, as at C. In every unjacketed and perhaps in jacketed engines, a point is reached before the curve terminates at O, at which the ratio of expansion becomes so large, the expenditure of steam so small and losses so great, that the curve falls nearly to the axis OX; thus instead of crossing OX, and extending through O', has a point of contrary flexure between C and O. The line O, C, E, A is thus representative of the class of mean pressure or efficiency curves given by actual engines. Could the variation of expenditure of heat be exactly expressed by an algebraic equation, this equation would be that of the line $ACEO$, and the problem would be capable of exact solution by algebraic methods.

Another, and, in some respects more readily understood, although less exact, method of constructing the curve of efficiency is to make the base scale a uniform scale *both* of steam consumption and of cut-off, as for adiabatic expansion, and then to make the ordinate, at any point, proportional to the quantity of work done at the given point of cut-off by the quantity of steam there measured, as was done in the preceding paper.

10. Solution of Problems of Efficiency for Actual Engines.

Draw HG at a height above OX equal to the back pressure, p_3; then the tangentline HK identifies a point K, which gives the ratio of expansion at *maximum efficiency of fluid*—since the ordinate GK meas-

ures the work done by the steam drawn from the boiler—and the ratio $\frac{GK}{HG}$ becomes a maximum at K. Drawing ML to represent the pressure demanded to overcome all useless resistance, $p_v = p_3 + p_f$, a similar construction identifies D as the point corresponding to the ratio of expansion at *maximum efficiency of engine.* Finally, extending this line to V and making VM proportional to cost of all variable running expenses, stated in terms of cost of steam per cubic foot of cylinder, $VM = \frac{A}{B} = M$, when working at full stroke, the tangent line VZ meets the curve at a point near D' which gives the ratio of expansion at *maximum commercial efficiency.* Comparing these values of r with those given by the tangents, HR, MP, VW, drawn to the curve OB, for dry saturated steam, expanded adiabatically, it is seen that the best ratio of expansion must be, in each actual example, less than in the hypothetical case and may even become unity for each kind of *efficiency,* with very slow piston speeds, where, were no loss of heat to occur in the manner here considered, considerable expansion would be desirable. These differences all become greater as the back pressures and current expenditures become less.

Making the value of VM a measure of the total current expenses including the constant as well as variable items of cost, of attendance, as those of rent, insurance, etc., which do not depend on size of engine, $VM = \frac{A'}{B} = N$, a value of r will be obtained which is that real ratio of expansion at which *maximum work is done for a given expenditure,* per hour or per annum, on a plant actually established. This problem is less frequently presented to the engineer than those already given, and is not the problem of maximum commercial efficiency; since this ratio and the corresponding power of engine being determined, it will be found on solving for maximum commercial efficiency that another proportion of engine with higher ratio of expansion will supply the power now demanded at still lower cost. To this latter engine the last problem again applies. The practical conclusion to be drawn from the solution of the interminable succession of problems of this last character, which thus follow the first, is that the largest amount of power possible should be entrusted to a single engineer, or crew of attendants, and placed under one roof, etc. In this last case, all

items become constant except those dependent upon the quantity of fuel burned.

Finally, the last of the problems enumerated at the beginning of this paper may be solved with equal ease, precision and satisfaction.

To ascertain just what ratio of expansion and what amount of work, as a maximum, can be profitably obtained from an established plant, calculate the net power obtainable from the engine without expansion, and the market value, or otherwise real value to the proprietor, of that power and estimate also, the cost of fuel and all items of cost variable therewith. Divide the price of power by this cost. Then lay off, on the base line appropriate to the given engine, the distance SV, produced, equal to the quotient, taking the distance MS as unity, and from the extremity of this prolonged base line draw a straight line TA, to the point A, at the altitude AS equal to the measure of the net power just calculated. Finally draw a line UA, parallel to this hypothenuse of the triangle so described, and tangent as at Z', to the curve of efficiency. The point of tangency Z' will identify the *minimum profitable ratio of expansion* and determine the maximum amount of work obtainable from this engine with profit. For, at this point of tangency the ratio of total cost of power to the price obtainable for it, or to its actual value, is that already given as the greatest permitting a fair profit while the ratio of expansion so determined is that giving that power at that rate of cost.

The value of the *Ratio of Expansion at Maximum Profitable Power* is evidently, in all actual examples, less, and the work done is greater, than in either of the preceding cases, and *is dependent upon the market value of that power.*

In all cases, the ratio of expansion calculated is the real ratio; the apparent ratio is decreased by clearance and increased, often considerably, by the wiredrawing which occurs just before the valve is seated. It is evident that loss of steam by leakage modifies the curve of efficiency in the same general way as loss of heat by cylinder condensation.

(To be continued.)

NINETY MILES IN SIXTY MINUTES.

By W. Barnet Le Van.

Read before the Franklin Institute, at the Stated Meeting, December 15, 1880.

So that it is safe, no railway speed can be too high, even were it one hundred and fifty miles an hour.

On the 19th of May last, I had the honor of reading a paper before this Institute on "High Railway Speeds," in which I made the following statement: "The writer believes that before the expiration of five years, with the present active rivalry between the Bound Brook and Pennsylvania Railways, passengers will be set down in New York City in one hour's time from Philadelphia."

Now this was no idle statement; it was based on facts and observations made by the writer on his trips between the two cities on the above railways.

If any one will take the time and trouble to examine the permanent way, especially that of the Pennsylvania Railway, by taking a position in the rear car commanding a view of the road-bed, he will be astonished at its serpentine path, and wonder how its speed is accomplished at all by its regular "flying trains," a distance of 88·4 miles to Jersey City, in 114 minutes, or from Germantown Junction, 84·2 miles, in 106 minutes. And his astonishment will be still greater when he is told that in the 88·4 miles the train passes over 84 curves, or nearly one for each mile of road-bed, varying from 5730 feet (one degree) radius to 636·3 feet (nine degrees).

The greatest length of continuous straight track, between Philadelphia and Trenton, 32·5 miles, does not exceed three miles; in fact, this part of the road-bed is a continuous series of curves and re-curves, thirty-five in number. The longest stretch of straight track on the entire road does not exceed ten miles, it is between Trenton and New Brunswick 25·5 miles apart, with 12 curves; between Trenton and Monmouth Junction the road is comparatively straight, but between the last named station and Rahway, it is similar to that portion of the road between Philadelphia and Trenton; from Rahway to Jersey City it is moderately straight. The distance between New Brunswick and Jersey City is 30·4 miles, with 37 curves.

With all these drawbacks the Pennsylvania Railroad Company regularly every day accomplishes a speed of 50 miles per hour, passing over the number of curves before stated, whose total curvature would describe over ten complete circles. What would they accomplish had they a perfectly straight and level permanent way?

The Bound Brook Railroad, being a comparatively new line, has a much better alignment, its length being, from Jenkintown to Bound Brook 49·1 miles, with but 18 curves, none of which exceed 2865 feet (two degrees) radius. The longest piece of straight track is from Skillman, east, 14 miles. This part of the road is leased by the Reading Railroad Company, which connects with it from Ninth and Green streets, Philadelphia, to Jenkintown, over the Germantown and Chestnut Hill and North Penn. branches, a distance of 10·1 miles, containing 17 curves varying from one to nine degrees radiûs. At Bound Brook the train is taken in charge by the New Jersey Central Railroad Company, who make a change of locomotives and haul it 30·2 miles, passing over 8 curves. Total distance from Philadelphia to Jersey City 89·4 miles, passing over 43 curves, making two stops, changing locomotives once, time 117 minutes.

The time occupied in crossing the Hudson river to New York from Jersey City on both lines is five minutes, making two hours for the through trip.

If the road-bed between the cities were straight and level there would be no alteration required to run the high speed of 90 miles an hour, but upon a curve the outer rail must be more or less elevated, so as to counteract the centrifugal force of the train due to its velocity, moderate speeds requiring less elevation than those of a higher velocity; from this it follows that curves on any road cannot be perfectly adjusted to trains moving at different speeds. The tractive power acts always tangent to the curve at the point at which the locomotive is, tending to pull the cars against the *inner* rail. The tangential force, generated by the motion of the cars, hereinafter more fully considered, tends to keep the flanges of the wheels against the *outer* rail, and only when just balance is made between the tractive and tangential forces will the wheel run without pressure against either rail.

Whenever the speed differs from that normal to the superelevation of the rail, the flanges of the wheel will grind against one rail or the other. Therefore, on any road where the speeds on the same curve, or the radii of curvature under the same speed, differ, there must be a loss of

power, and the flanges must drag or slide against the rails. Where the outer rail is superelevated for high speeds, the slow moving trains will grind against the inner rail.

Mr. McCallem estimates the resistance at one-half pound per degree (5730 feet) radius of curvature per 100 feet, that is to say, the resistance due to curvature on a four degrees (1432·5 feet) radius would be two pounds per ton.

Mr. D. K. Clark estimates the resistance due to a curve of 5280 feet radius, and under, as 6·3 pounds per ton, or twenty per cent. of the whole resistance.

Centrifugal Force of Bodies Moving on Curved Roads.

All moving bodies tend to move in a straight line, and hence a body moving in a curve is continually being constrained by force at right angles to its path, the centrifugal force acting horizontally at right angles to the direction of the rail. Centrifugal force on railway curves is very considerable on curves of small radius, and the outer rail has to be raised to prevent the train from falling over sideways, but with a curve of great radius and moderate speeds the conical inclination of the wheel face increases the radius of the outer rolling surface and somewhat counteracts the centrifugal force.

When high speeds are used and the rail has to be elevated, the amount of elevation is given by the following formula:

Let

h = height of rail in inches.
M = miles per hour.
R = radius of curve in feet from centre of track.
G = gauge of track.
15 = constant number (14·956 exact).

$$\frac{h}{G} = \frac{M^2}{14{\cdot}956} = h = \frac{GM^2}{15R}.$$

This formula is not strictly correct, because $\frac{h}{G}$ is *sin x*, instead of *tan x*, but the difference is of no practical importance in the small angle of elevation of the outer rail in railroad curves.

Take as an example a curve of (3 degrees) 1910 feet radius, the superelevation on a gauge 4 feet $8\frac{1}{2}$ inches (56·5 inches), the outer rail would be as follows for different speeds:

Miles per hour.	Superelevation of outer rail in inches.
20	0·78
30	1·77
40	3·15
50	4·92
60	7·09
70	9·66
80	12·62
90	16·

With this elevation the wheels would bear equally on *both rails*. For slower speeds on same curve the wheels would bear more heavily on the *inner rail* than on the outer.

On the Pennsylvania Railroad the superelevation is one inch for each degree of curvature up to *five inches* as maximum, which is never exceeded regardless of the speed or curvature in degrees; that is to say, by its rules the engineer on approaching a curve of three degrees radius at the rate of 50 miles per hour *must slack down his speed to 40 miles*, to correspond to the superelevation of outer rail.

Curves are not objectionable on the score of loss of power, though highly so from their *wear and tear of locomotives and cars, displacement of rails, danger*, etc.

The *danger* of running off the track is much increased by curves, even of large radius, especially at high speeds. The momentum of the cars impels them onward in a straight line, and they are kept on the rails on striking a curve only by the flanges, the resistance of which gradually makes them follow the curvature of the road. If the momentum should exceed the resisting force, the cars must obey the former and leave the track.

D. K. Clark says that he found "that, with a passenger train on the Caledonian Railway going 45 miles per hour, the resistance rose from 28 to 34 pounds per gross ton, as measured by an indicator on the cylinders when the train passed upon a portion of the line having curves of less than one mile (5280 feet or about one degree) radius, but more than half mile radius, averaging 2⅝ curves per mile. The increase in this case of resistance caused by the curves was more than 20 per cent. of the resistance on the straight part of the line."

The increased resistances in these cases was partially due to the rigid wheel base on European lines. Our system of four-wheeled

pivoted trucks, or "track feeler" with its fifth wheel, enables the locomotive and cars to turn sharp curves more safely and easily and at a less resistance.

The resistance of trains, and the injury they produce to the road, are directly as the weights, and, on the other hand, are nearly directly as the speeds.

The resistance occasioned by concussions, whatever they may be, at any given velocity, must vary as the square of that speed.

The variable resistance from concussions at any given speed depends entirely on the condition of the track.

It has been demonstrated by the use of a dynamometer-car that on the best constructed railroads in this country the inequalities of rails and joint-connections add about *seven feet in grade per mile.*

This difference is so great, that there is abundant reason to believe that a train of given weight will run more easily with the same power at ninety miles an hour, on a straight and level railroad, than one of the same weight at sixty miles an hour on a road made up largely of curves and grades.

The curvature of European lines is generally favorable. The shortest curve, between London and Birmingham, England, distance 130 miles on the main line of the Northwestern Railway, is one of 1800 feet radius (about three degrees).

In alignments, the European roads are much superior to ours.

Advantages of a Straight and Level Line.

The great cost of the superstructure of a railroad, and the continually increasing expenses of keeping it in repair, render it highly desirable that it should be as level and straight as possible.

Earthwork of a railroad costs almost nothing for repairs, proportioned to its length, as is also the cost in fuel, wages, and wear and tear of the locomotive and cars; it will therefore be advantageous to make large expenditures in building a straight and level road in the first place in order to lessen the length, and consequently the annual expenditures on the superstructure.

To run a train at ninety miles an hour, not only must the permanent way be of the best character, and in the most perfect state of repair, but also the rails must be laid in the best manner and with all the best appliances conducive to strength, and the joints, as far as practicable, should be of equal strength with the other portions of the rail.

Speed is an important element, and it is far more important that good roads should be fitted to speed, than that speed should be fitted to bad roads. The limit of the locomotive weight is what the rails can safely bear.

Dead Weight.

Another important question in moving passengers at high speeds is how to diminish the dead weight of the cars. From the engineer's standpoint a passenger is taken as a package, of an average weight of 150 pounds, and the problem really is how to carry these packages with as little additional weight as possible.

The power required to overcome the resistance due to mere weight of such a package, at a speed of 90 miles an hour on a level, is but about one and a half horse-power, and one hundred passengers would require about 150 horse-power. But, while this will carry the live weight of the train as now "made up," it will require twenty to thirty times as much power to pull the whole weight *live* and *dead*.

And from long habit we have become reconciled to this excessive and monstrous waste of power, and to the annual expense due to the destruction of the superstructure.

In the language of a celebrated engineer, "we might as profitably draw the stations themselves, and for that matter the towns about them, as to move the lumbering structures which now make up a railway passenger *train*. The passengers themselves require but little power to draw them, their weight produces but little *wear* upon the *rails*, but little *strain* upon the *superstructure*, and yet to put them into motion we set going a small village of houses on wheels, with a great thundering locomotive, weighing, all told, from thirty to sixty tons (for the tender counts with the locomotive), and for all this we have to provide superstructures of immense strength, of which the most costly portions are, naturally and necessarily, being constantly knocked to pieces."

So accustomed have we become to this system of movement that we are reconciled to, if not really proud of, the cost which it entails, and we pay our fares as we pay our *taxes* or *gas bills*.

The real question of *rapid transit* of passengers and *cheap fares* turns, not upon their own weight, but upon that to be taken along with them. So far as their own weight is concerned, we might easily shoot twenty passengers through a tube from Philadelphia to New

York or Boston, the one journey occupying twenty minutes and the other an hour; and we might send such a *train* every fifteen minutes.

We cannot carry our passengers through the air unsupported by seat or car of any kind. If we could, all dead weight would be saved. But to run 90 miles an hour on our ordinary superstructure we must reduce the surplus weights.

As our trains are now made up to carry from four to eight tons of passengers, we put in motion a train weighing from 110 to 150 tons—a train in which the locomotive alone weighs about 35 tons, most of the rest being dead weight.

According to the report of one of our leading railroads for 1878–79, the average weight of cars in passenger trains was estimated at 110 tons, and the average number of passengers carried was 60·1 to 61·4, which gives $1\frac{5}{6}$ tons (3666 pounds) of *car* hauled per passenger. On the London and Northwestern Railway Company, England, an account was taken at a period of the year which might be taken at a fair average both ways. It was found that 4482 passengers left London in trains containing seats for 13,512 passengers, and 4337 passengers arrived in trains that would accommodate 13,333 passengers.

Therefore, to span ninety miles an hour, the "make up" of our trains in regard to the dead weight must be carefully looked after.

The regular flying trains between Philadelphia and New York, on both the Pennsylvania and Bound Brook routes, consist of the following:

One locomotive and tender, dead weight,		. 89,000
One baggage car,	"	. 26,000
One parlor car,	"	. 45,000
Two passenger cars,	"	. 72,000
Total,	. . .	. 232,000

Total four cars with locomotive and tender, 232,000 pounds, or 116 tons dead load; length of train, about 264 feet.

The average carrying dead weight to paying weight on the Pennsylvania Rairoad is *sixteen* of *dead weight* to *one* of *paying weight*, very nearly, on fast passenger trains.

Mr. John Burroughs says, in making a comparison between the English prudence and plain-dealing, that "they put so little on the cars and so much on the road, while the reverse process is equally characteristic of American enterprise. Our railroad system, no doubt, has

certain advantages, or rather conveniences, over the English; but, for my part, I would rather ride smoothly, swiftly and safely in a luggage-van (baggage-car) than be jerked and jolted to destruction in the velvet and veneering of our palace cars. Upholster the road first, and let us ride on bare boards until a cushion can be afforded; not till after the bridges are of granite and iron, and the rails of steel, do we want this more than aristocratic splendor and luxury of palace and drawing-room cars. To me there is no more marked sign of the essential vulgarity of the national manners than these princely cars and beggarly clap-trap roads. It is like a man wearing a ruffled and jeweled shirt-front, but too poor to afford a shirt itself. Their locomotives are less noisy than ours, having a shrill, infantile whistle that contrasts strongly with the loud demoniac yell that makes a residence near a railway or station, in this country, so unbearable (whistling on the eastern part of Pennsylvania Railroad is almost abolished; nine-tenths of the whistling is unnecessary). The trains themselves move with wonderful smoothness and celerity, making a mere fraction of the racket made by our flying palaces as they go, swaying and jolting, over our hasty, ill-ballasted roads."

Horse-power.

Of horse-power in connetion with locomotives we do not often speak; but no just comparison of the performance of different locomotives can be made unless some standard practically corresponding to horse-power be adopted for the purpose. A locomotive in pulling a train at *forty* miles an hour exerts at least twice the absolute power which it would put forth in moving the same load over the same road at *twenty* miles an hour, even if the "traction" be the same in both cases. In connection with my subject, as I may mention the performance of locomotives, I shall estimate, as nearly as may be, the horse-power exerted. The horse-power, it will be seen, is the result of multiplying the total resistance of the locomotive and train, in pounds, by their velocity in feet per minute, and dividing the product by 33,000. If the "dead pull" of a train be 20,000 pounds, the resistance is, of course, the same, whether it be overcome by the horizontal motion of the locomotive, or lifted vertically, as a weight of 20,000 pounds, the performance of the locomotive being, in any case, convertible into horse-power.

The horse-powers of the locomotives hauling the flying trains on the

Pennsylvania and Bound Brook routes between Philadelphia and Jersey City are as follows:

No. 411 of the Philadelphia and Reading Railroad (one of a number, running fast passenger trains between Philadelphia and Jersey City on the Bound Brook route) developed 1006 horse-power on Dec. 20th, 1880, hauling four fully loaded passenger cars from Philadelphia to Bound Brook. The day was one of the coldest of the season, the thermometer marking six degrees below zero, Fahrenheit. Notwithstanding the unfavorable influence of a brisk north wind, a speed of 72 miles per hour was attained upon a level while cutting off steam at 8·625 inches.

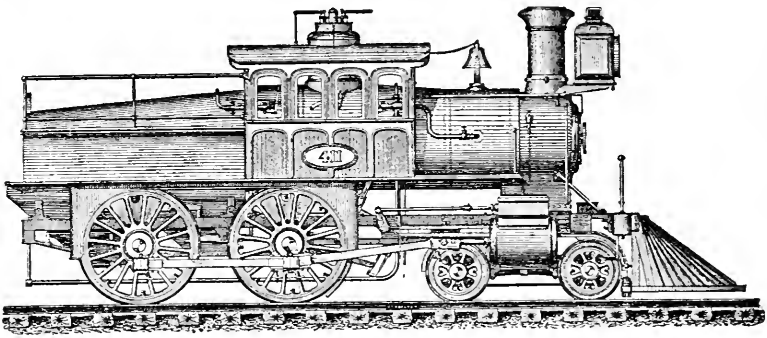


Fig. 1.

The following indicator diagram was taken at the speed above stated, viz.:

$$\text{HP} = \frac{343 \times 1260 \times 38\cdot4}{33000} \times 2 = 1006 \text{ horse-power}$$

Scale of indicator, 80 pounds equal one inch.

Diameter of cylinder in inches,	21·
Diameter of piston rod in inches,	3
Length of stroke in inches,	22·
Revolutions per minute,	360·
Boiler pressure per square inch,	105·
Point of cut-off in inches,	8·625
Diameter of driving wheels in inches,	68·
Total weight of locomotive in pounds,	98,200
Weight on drivers in pounds,	64,250
Total heating surface in square feet,	1117·
Total weight of train complete in tons,	175·

Several miles were run continuously in less than 50 seconds.

The following indicator diagram was also taken on the same locomotive May 4, 1880, the train consisting of seven passenger cars, and the speed at the time of taking the diagrams was at the rate of 64

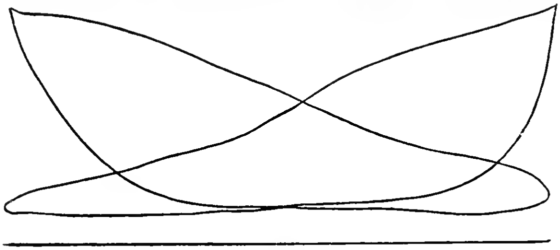


Fig. 2.

miles per hour, or 316 revolutions per minute; boiler pressure, 123 pounds per square inch, and point of cut-off 6·5 inches; complete weight of train about 200 tons.

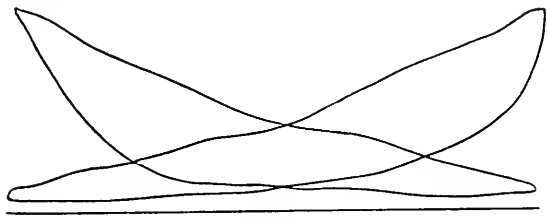


Fig. 3.

$$\text{IP} = \frac{343 \times 1156{\cdot}5 \times 24}{33000} \times 2 = 580 \text{ horse-power.}$$

The tractive force exerted for each pound of effective pressure per square inch in the piston is:

$$\frac{21^2 \times 22}{68} = \frac{441 \times 22}{68} = 142{\cdot}68 \text{ pounds.}$$

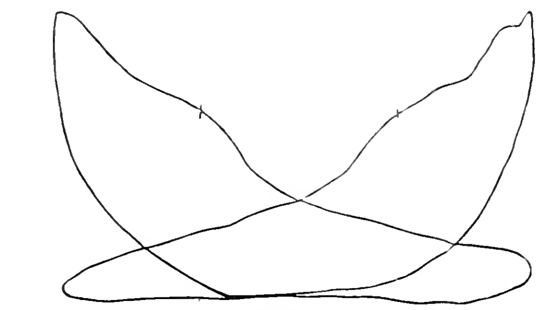


Fig. 4.

The above indicator diagram was taken from locomotive No. 10, "Class K," of the Pennsylvania Railroad, when running at the rate of 64 miles per hour, cutting off at 7 inches.

$$\text{HP} = \frac{251 \times 1104 \times 40{\cdot}3}{33000} \times 2 = 676{\cdot}8 \text{ horse-power.}$$

Diameter of cylinder in inches,	18
Diameter of piston rod in inches,	3
Length of stroke in inches,	24
Revolutions per minute,	276
Point of cut-off in inches,	7
Boiler pressure in pounds,	140
Diameter of drivers in inches,	78
Total weight on drivers in pounds,	65,300
Total heating surface in square feet,	1205

The tractive force exerted for each pound of effective pressure per square inch in the piston is:

$$\frac{18^2 \times 24}{78} = \frac{324 \times 24}{78} = 99{\cdot}7 \text{ pounds.}$$

The locomotive *Precursor* of the London and Northwestern Railway, England, from the design of Mr. T. W. Webb, superintendent, running at a speed of 58 miles per hour, corresponding to 295·4 revolutions or

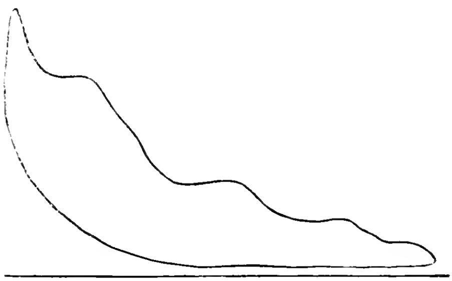


Fig. 5.

a piston speed of 1181·6 feet per minute, the reversing screw being $3\frac{1}{2}$ turns back and the boiler pressure 123 pounds per square inch, the mean effective pressure being 32·7 pounds, developed 531·5 indicated horse-power. (*Engineering*, vol. 19, p. 185.)

The tractive force exerted for each pound of effective pressure per square inch on the piston is

$$\frac{17^2 \times 24}{66} = \frac{298 \times 24}{66} = 106{\cdot}09 \text{ pounds.}$$

This locomotive runs the Scotch Express between Crewe and Carlisle, the average weight of the trains is about 187 tons with a consumption of 33·2 pounds of fuel per mile.

The highest horse-power that any locomotive has developed, to my knowledge, is that of the locomotive "No. 5000," the 5000th built by the Baldwin Locomotive Works, on a trial trip on Friday, May 14, 1880, from Ninth and Green streets, Philadelphia, to Jersey City and return, each way without stopping. Weight of the train complete, about 148 tons.

On this trip 2·8 miles were run in *two* minutes, part of which distance was an ascending grade of 16 feet per mile; being at the rate of *eighty-one miles per hour.*

The average point of cut-off was at half-stroke, and the boiler pressure 130 pounds per square inch above the atmosphere, which would correspond to an average effective pressure of 50 pounds per square inch upon the 18-inch pistons and a stroke of 24 inches, the driving wheels being 78 inches in diameter and making 350 revolutions per minute.

The effective horse-power was as follows:

$$\text{HP} = \frac{251 \times 1400 \times 50}{33000} \times 2 = 1022 \text{ horse-power}$$

when running 81 miles an hour.

The average rate of speed to and from Jersey City was 54 miles per hour, the average effective steam pressure being 40 pounds per square inch and the number of revolutions 232 per minute.

The horse-power corresponding to the above data will be as follows:

$$\text{HP} = \frac{251 \times 928 \times 40}{33000} \times 2 = 564 \text{ horse-power.}$$

The actual evaporation of water per minute was 290 pounds or 17,400 per hour, or 30·5 pounds per hour per horse-power.

Within certain limits, the faster a locomotive is driven the more total power it may be made to exert; for locomotives, with sufficient boiler power, will keep up their steam as well and deliver it as effectively upon the piston at ninety miles an hour as at forty.

If the same total pressure be exerted upon the pistons in both cases, there will, of course, be three times as much power expended at the higher speed. A freight locomotive, therefore, running at 15 to 20 miles an hour, must be very powerful to exert 400 horse-power,

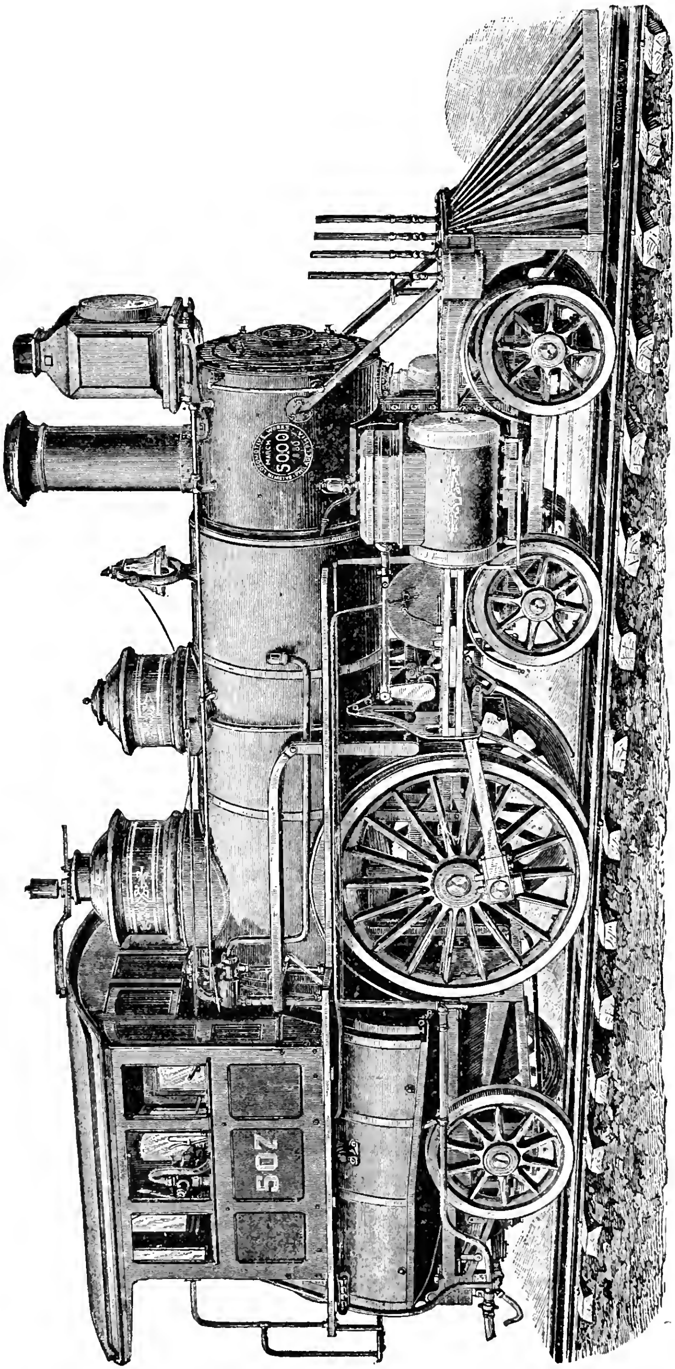


Fig. 6.

whereas the same power may be easily attained with a moderate sized passenger locomotive running at 90 miles an hour.

At the present time the steam pressure per square inch does not exceed 150 pounds; this pressure, however, is not used beyond a moderate degree of expansion, the piston speed averages about 1000 feet per minute and the locomotive averages 30 tons weight. Now, to obtain the increased power necessary to run 90 miles an hour the weight must be increased, or to maintain the same weight, the additional power must be sought in an increase of the speed of the piston and a corresponding increase of boiler pressure. The gain in increased piston speed will be as follows: With the same pressure per square inch as now used, a 10-inch piston at 1000 feet per minute gives off the same power as a 20-inch piston at 250 feet per minute.

A 15-inch cylinder locomotive, with 21 inches stroke and 72-inch driving wheels will, at any given steam pressure per square inch on the pistons, have the same tractive power as a 20-inch cylinder locomotive with 24-inch stroke and 12-feet driving wheels.

But for given speed in miles per hour, the piston of the former locomotive must move twice as fast as that of the latter; thus, at 90 miles an hour, the piston of the 15-inch by 21-inch stroke locomotive would move 1470 feet per minute, while that of the latter would move at the rate of 840 feet in the same time. There is a practical advantage, well enough known to experienced locomotive engineers, in a quick reciprocation of piston, the action on the fire or draft being far easier and more effective than when larger volumes of steam are exhausted up the chimney at longer intervals. In fact, the more frequent exhausts of steam into the chimney enables a smaller boiler to evaporate more water from a given heating surface in an hour than a larger boiler with less number of exhausts in the same time. For high speeds of piston, almost the only limit lies in good road-beds, and especially in correct counterweighting of the reciprocating and other disturbing parts, together with larger wearing surfaces and ample provision for taking up wear in the journals and brasses.

By increasing the boiler pressure to 200 or 250 pounds per square inch and expanding from $\frac{1}{10}$ to $\frac{1}{4}$ of the stroke (which can be accomplished by a separate cut-off valve), instead of $\frac{3}{8}$ and $\frac{1}{2}$ as now, the same power will be produced, only one-half the weight of steam (*water*) would be used and consequently but half as much water would require to be evaporated and but half as much fuel burnt. This direct saving

of fuel is of some consequence, but its importance is perhaps less than that of the corresponding weight of the boiler, water, etc., at the same time effected, for it is evident that but about one-half the weight of boiler would be required to evaporate 10,000 pounds of water per hour that is required now for 20,000 pounds.

The power of locomotives depends principally upon two elements, their heating surface and their adhesive weight—that is to say, the weight resting upon the driving wheels.

All experiments show that the faster a locomotive runs, the greater is the production of steam per square foot of heating surface and consequently the greater is the amount of work developed. As far as the production of steam is concerned, it is therefore advisable to increase the speed as much as can be done without injury to the working parts.

Adhesion.

The adhesion of a locomotive is the measure of its power. The quantity or water evaporated in pounds per hour is the only real standard of the power of a boiler, and fast-running locomotives must necessarily have greater boiler capacity than those intended for slow speeds.

At a speed of 45 miles an hour, the resistance of a train of given weight may be 25 pounds only per ton, while at 90 miles an hour the resistance may be 60 pounds per ton. The resistance does not increase in the direct ratio of the speed; for, as before shown, the mere rolling friction is constant at all speeds, while the resistance due to blows, concussion, jolts and the atmosphere, increases as the square of the speed. The above shows the importance of having the road-bed and superstructure in the best condition, level and straight, so as to reduce the factor of resistance to that of the atmosphere.

Mr. Gooch's experiments, over thirty years ago, showed us that upon a good line the resistance at even 60 miles an hour was not much greater than 20 to 25 pounds per ton; and we may conclude, therefore, that on an equally good or better road, 40 pounds per ton would cover all the resistances at 100 miles an hour, and thus that a locomotive and cars weighing 150 tons could be moved at that speed with 4000 pounds tractive force, corresponding to 60 pounds mean cylinder pressure on a piston of 15 inches diameter and 21 inches stroke and indicating 1000 horse-power.

The amount of adhesion required to turn to account the whole

power which a locomotive is capable of developing varies, inversely, as the speed at which the locomotive is run—*the higher the speed the less being the adhesion required.*

Take a locomotive capable of supplying steam sufficient to develop in the cylinders 10,000,000 foot-pounds of work per hour over and above that required to overcome the frictional or other resistances of the locomotive itself. If, now, the engine is moving at a speed of but 1000 feet per minute, or about 12 miles per hour, a pull of 10,000 pounds will have to be exerted to use up the power developed, and the adhesion will have to be such as will enable this pull to be exerted without causing the locomotive to slip. If, however, the speed of the engine be increased to 8000 feet per minute, then the pull necessary to use up to 10,000,000 foot-pounds of available work developed per minute in the cylinders would be

$$\text{Work} = \frac{10{,}000{,}000}{8000} = 1250 \text{ pounds only,}$$

and the adhesion weight required would be only *one-eighth* of that that necessary in the case first supposed.

From the above it will be seen that in locomotives running at slow speeds, it is desirable to have a great proportion of the weight available for adhesion, yet in the case of fast-running locomotives this is by no means always necessary; particularly if the trains run by fast locomotives do not require to be started very quickly. In freight and shifting locomotives, running at slow speed, coupled wheels have all the available weight for adhesion, but at high speeds this advantage ceases.

The cost of moving trains at any given speed is, all other things being equal, almost exactly in proportion to the weight moved; the only difference being in the cost of engineers, conductors, etc., which would be nearly the same for a light as for a heavy train. The average weight of passenger trains, including locomotive and tender such as are used on the flying trains between Philadelphia and New York, may be set down at 120 tons. The average cost of running trains, including fuel, repairs, stores and maintenance of way, is about *four* cents against *one* cent in England per ton per mile. Of the whole cost, it is very evident that it costs more to move each ton of the weight of the locomotive than of the cars; and so, too, the cost of moving a ton of wheels, axles or other weight below the springs, and in direct contact with the track, is much greater than the cost of an equal weight above the springs.

(To be continued.)

A NEW FORM OF REVERSIBLE STEREOSCOPE.

By W. LeConte Stevens.*

With a view to removing for others the difficulty implied in the binocular experiments on which I based the conclusions expressed in my recent papers, published in the November and December numbers of this journal, I have devised the following form of stereoscope, which has been found quite satisfactory. Persons possessing no previous muscular training of the eyes have been able with it to secure reversion of relief in the combined picture as easily as they had obtained natural perspective while using it as an ordinary stereoscope. Some of my experiments involved extreme muscular tension; these required the use of the unaided eyes, but a large proportion of the rest can be performed by the aid of this instrument without special discomfort. It has been constructed for me by Messrs. E. & H. T. Anthony & Co., of this city.

The semi-lenses (Fig. 1, *l*, *l*) rest in a pair of boxes, with windows in front and behind, to transmit the light. These boxes are separated by a thin partition, on each side of which is a spring against which the thin edge of the semi-lens is pressed by the adjusting screw (*s*) at the base. In front is a pair of brass hinges (*c*, *c*); when pressed flat, as in Fig. 1, each half of the stereograph is hidden from the eye on the other side; when folded, as in Fig. 2, the whole stereograph is made visible to each eye. Attached to a sliding cross-bar is a wooden screen (*b*, *b*), moving on hinges; when this is pressed down flat, as in Fig. 1, the view of the stereograph is unobstructed; when lifted up, as in Fig. 2, the window at the middle permits the left half of the stereograph to be seen by the right eye, while the right half is obscured; and vice versa for the left eye. From the top of this window is a small projection (*d*). The stereograph rests upon its movable cross-bar (*a*), which slides upon a longitudinal strip about 30 cm. in length.

The semi-lenses are easily removable at will, and a pair of prisms (*pp*), the refracting angle of which is 12°, can be substituted, but with their bases pressing against the springs instead of the screws.

* From the *American Journal of Science*, vol. xxiii, March, 1882.

To secure natural perspective through the semi-lenses press the brass and wooden screens flat (Fig. 1), and use the instrument as an ordinary stereoscope. Assuming the stereographic interval to be average, and the distance between the observer's eyes to be not greater than usual, comfortable vision will be secured by turning the adjusting screws until the semi-lenses are pressed as near as possible together. The light which enters the pupils then passes through the thicker part of each semi-lens, and the optic angle is positive and small, or

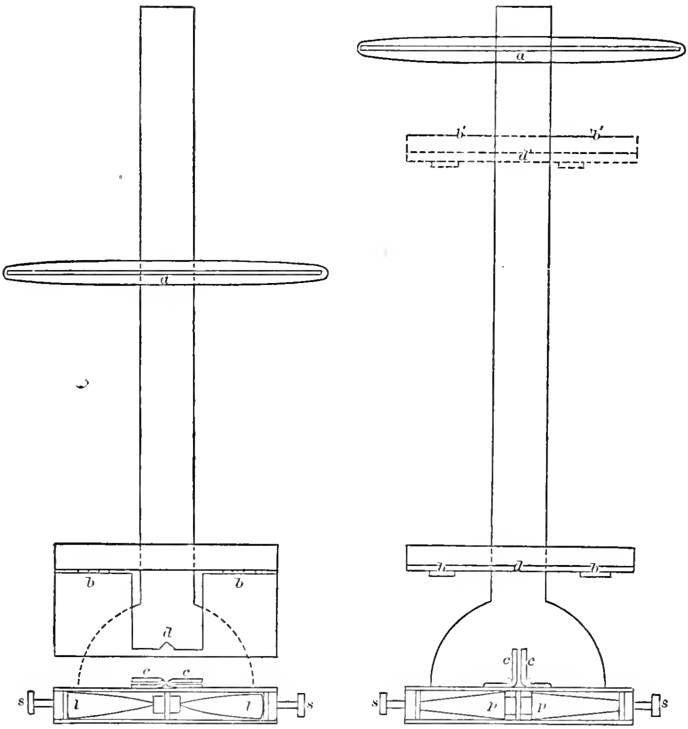


Fig. 1. Fig. 2.

the visual lines may be sensibly parallel. If the observer's interocular distance is much greater than usual, the rays of light which he receives will be transmitted still nearer the base of the semi-lens, and slight optic divergence is necessary. This is avoided by giving a few leftward turns to the screw, permitting the semi-lenses to be pressed a little farther apart by the opposing springs. The same can be done to secure comfortable vision when the stereographic interval is great;

pictures 10 cm. apart can thus be viewed without discomfort, and without any very objectionable degree of coloration in consequence of want of achromatism in the semi-lenses. By now turning the screws so as to press the glasses closer together, any degree of optic divergence may be attained that the observer is willing to endure, while the picture is still seen in natural perspective, distances being apparently slightly magnified, and diameters also in the same ratio.

To secure reversed perspective, lift up the wooden screen, fold the brass hinges outward in front, and substitute the prisms for the semi-lenses, as in Fig. 2. Slide the stereograph nearly to the end of the stereoscope. Physiological perspective is at once reversed; whether this is enough to overpower the other elements of perspective must depend upon the nature of the picture. If the stereograph be that of the moon, the reversion is complete; if of terrestrial scenery, some objects may be apparently transposed in position while others are not. The same picture may be examined successively with each illusive effect several times in as many minutes. As soon as reversion is attained the stereograph may be drawn up as close as may be convenient.

If both semi-lenses and prisms are discarded, the instrument becomes a direct-vision stereoscope, in some respects similar to that described by Prof. William B. Rogers in 1855. To secure natural perspective press the screens flat, pull the stereograph up as close as possible, and gaze as if through it at a remote object, with the muscles of the eyes relaxed. The two pictures, imperfectly focalized, are dimly seen apparently to overlap. The stereograph is then pushed out to the end of the stereoscope, and the pictures are binocularly combined by optic divergence. The stereograph may now be pulled up as near as convenient.

To secure reversion of perspective by direct vision fold the brass hinges and lift the wooden screen, as in Fig. 2. Push this out (b' b') as near as possible to the stereograph at the end of the instrument, then pull it up, keeping the gaze fixed upon the projection (d') at the top. This grows dim as it approaches its previous position. Without changing the direction of the visual lines, except slightly to lower them, transfer the attention to the stereograph beyond. The combined picture is seen in reverse perspective, apparently much smaller and nearer than when the prisms were employed.

Those who have tried this instrument thus far have usually suc-

ceeded at the first attempt, for either natural or reverse perspective, when the glasses were used. Several trials are often necessary before success is attained by direct vision, but the variation in perspective thus attained is much more striking. But little experiment is needed to prove to any one who is thus successful that in the localization of objects in the binocular field of view presented by the stereograph, the current theory of successive triangulation by intersection of visual lines is inapplicable. The only substitute that covers the facts which the geometric theory fails to account for is that of associated muscular action, which applies to divergence as well as convergence of visual lines.

The use of adjusting screws for the semi-lenses of the stereoscope is, of course, not a novelty. They were thus applied by Duboscq, about 1850, to one of Brewster's stereoscopes, and also, subsequently, by Helmholtz. A similar application is especially described by Prof. Emerson in this journal, Nov., 1861, and Emerson's stereoscope was for a number of years made by Messrs. Anthony & Co., of New York. It would indeed be difficult to evolve any wholly new principle in the construction of stereoscopes. The present instrument was devised for a specific purpose, which it accomplishes successfully.

40 West Fortieth street, New York, Jan. 21st, 1882.

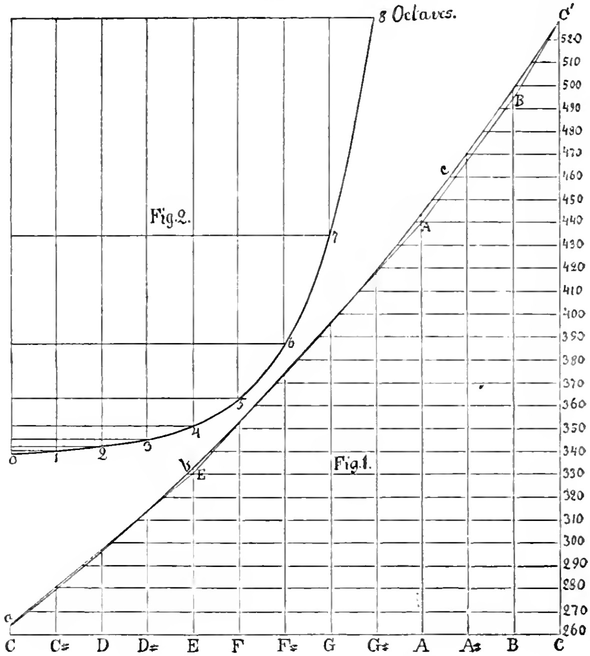
INTONATION OF CHIME-BELLS.

By John W. Nystrom.

The harmonic intonation of the musical scale can produce good music only in the one key for which it is toned, and is therefore unsuitable for musical instruments including peals of bells, upon which it is expected to be played equally well in any one of all the different keys. The harmonic intonation divides the musical scale into an irregular order, found to be most agreeable to the ear and can be used only in vocal music, but for musical instruments it has been found necessary to divide the scale into a regular order called the tempered scale. In his extensive and excellent work on "The Sensations of Tone" Helmholtz gives various methods of tempered intonation, each named after its respective author; but none of these methods, as far as the writer has been able to find, has given a perfectly tempered intonation.

The writer's attention has been called to this subject in the construction of peals of bells which are required to ring music in different keys. A peal of eight bells, or an octave of the diatonic scale with harmonic intonation, can ring harmonic music only in the key for which it is toned and will be wrong for any other key, even if one or more bells are added to the peal. A peal of any number of bells, with tempered intonation, can ring equally correct in any one of all the keys.

The pitch of tone produced by any vibrating body is proportionate



to the number of vibrations per unit of time usually expressed *per second*. The octave above any tone makes double the vibrations of its octave below, and each note in the musical scale has a definite number of vibrations depending upon its position.

For the tempered intonation of the musical scale, the number of vibrations of each note is a term in a geometrical progression, that is, the vibrations of any one note, multiplied by a certain ratio, give the vibrations of the next note above. The octave is divided into twelve equal parts, making thirteen terms, including sharps or flats. We

have now all the data necessary for the tempered intonation by the formulas of geometrical progression.

$C =$ first term, or vibrations of the fundamental note.

$c =$ the last term, or vibrations of the octave above the fundamental note. $2\,C = c$.

$n =$ number of vibrations of any note in the musical scale whose number of terms, from C inclusive, is a.

$a =$ number of terms between C and n inclusive.

$r =$ ratio of vibrations between each note or term.

Each term multiplied by the ratio r gives the next following term, when the progression is increasing.

$$\text{Ratio } r = \sqrt[a-1]{\frac{c}{C}} \cdot \text{ Vibrations } n = C\,r^{a-1}.$$

In the application of these formulas to the division of the octave into the chromatic scale of thirteen notes, we can assume any arbitrary number of vibrations of the fundamental note, say $C = 32$, and the octave will then vibrate $c = 64$, making $a = 13$, we find the

$$\text{Ratio } r = \sqrt[a-1]{\frac{c}{C}} = \sqrt[13-1]{\frac{64}{32}} = \sqrt[12]{2.}$$

$$\text{Log. } r = \frac{\text{log. } 2}{12} = \frac{0{\cdot}30102999566}{12}$$

$$= 0{\cdot}02508583 = \text{log. } 1{\cdot}059462 \text{ the ratio.}$$

The proportionate vibration of any note, whose number from C inclusive is a, will be

$$n = C\,r^{a-1} = 32 \times 1{\cdot}059462^{a-1}.$$

The number a includes also the half-notes or sharps.

Example.—The note G is the eighth term above C, making $a = 8$; how many vibrations will G make?

$$\text{Vibrations } n = 32 \times 1{\cdot}059462^{8-1} = 47{\cdot}9458, \text{ the answer.}$$

The calculation is easily accomplished by logarithms, as follows:

log. 1·059462	= 0·02508583
multiply	7
	0·17560081
log. 32	= 1·50515000
log. 47·9458	= 1·68075081

The harmonic intonation of the diatonic scale is established as follows:

TABLE I.

	C	D	E	F	G	A	B	c
	1	$\frac{9}{8}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{5}{3}$	$\frac{15}{8}$	2
Harmonic,	32	36	40	$42\frac{2}{3}$	48	$53\frac{1}{3}$	60	64
Tempered,	32	35·9188	40·3175	42·7149	47·9458	53·8174	60·408	64
Difference,	0·000	—0·0812	+0·3175	+0.0483	—0·0542	+0·4841	+0·408	0·000

The actual number of double vibrations, per second, of the standard concert pitch now generally used was established by a Congress of Philosophers, which met in Stuttgart in the year 1834, namely, $C' = 264$, $A' = 440$ and $C'' = 528$. With this data the following table is calculated.

The Italic numbers of vibrations in the harmonic column n' are inserted by the writer, being the mean difference between the whole notes. The harmonic scale, as established at Stuttgart, advances in an arithmetical progression with constant differences in different portions of the octave. The difference in vibrations, between each half note, is 16·5 from C to E, 22 from E to A, 27·5 from A to B and 33 from B to C. Thus, the terms of vibrations do not form a regular curve, but a broken straight line making corners at E, A and B, as shown in the accompanying illustration, Fig. 1. It is, indeed, singular that such an irregular progression can bear the title of *harmonic*.

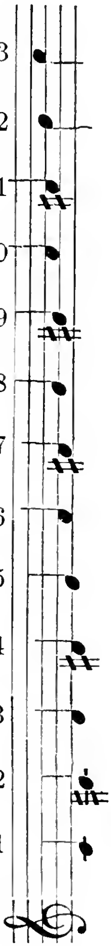
The tempered intonation, column n, ascends in a geometrical progression forming a regular curve a, b, c, C', Fig. 1. The difference in vibrations between each half note increases in a regular order, and the vibration of each note bears a certain ratio to that of the next one above or below. The two centre columns in the table show the difference between the two systems of intonation.

The last column, "Prop. length of waves," shows the proportionate diameters of bells for the corresponding note, when the sound-bow is of a certain proportion to the diameter in all the bells. This column also shows how to divide the bridge on a *guitar*, when the whole length of the string being 1 or the unit.

The tables III to VI contain the vibrations of each note in the chromatic scale, commencing with $C = 33$ vibrations and extend through eight octaves to $C = 8448$ vibrations per second, with the corresponding logarithms. Tables of this kind are necessary for the proper proportions and construction of peals of bells.

Table II.

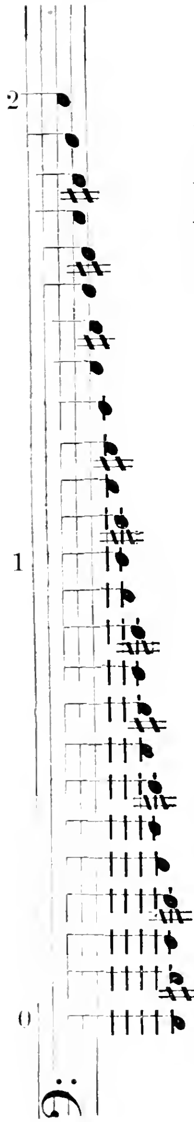
Harmonic and Tempered Intonations.



Stuttgart Harmonic Scale.			Difference.		Tempered Geometric Scale	
Terms a	Keynote.	Double Vibrations n'	Ratio of Pitch $\frac{n}{n'}$	In Vibration. $n-n'$	Double Vibrations n	Prop. Length of waves. $\frac{264}{n}$
13	C	528	1·00000	0·000	528	0·50000
		33			29·635	
12	B	495	1·00680	+3·365	498·365	0·52973
		27·5			27·970	
11	A♯	*467·5*	1·00616	+2·895	470·395	0·56123
		27·5			26·402	
10	A	440	1·00908	+3·993	443·993	0·59461
		22			24·919	
9	G♯	*418*	1·00257	+1·074	419·074	0·62996
		22			23·519	
8	G	396	0·99887	—0·447	395.553	0·66742
		22			22·201	
7	F♯	374	0·99827	—0·648	373·352	0·70711
		22			20·954	
6	F	352	1·00113	+0·398	352·398	0·74915
		22			19·787	
5	E	330	1·00794	+2·611	332·611	0·79370
		16·5			18·660	
4	D♯	*313·5*	1·00144	+0·451	313·951	0·84090
		16·5			17·621	
3	D	297	0·99774	—0·670	296·330	0·89090
		16·5			16·638	
2	C♯	*280·5*	0·99714	—0·808	279.692	0·94388
		16·5			15·692	
1	C	264	1·00000	0·000	264	1·00000
		16·5			14·817	

Table III.

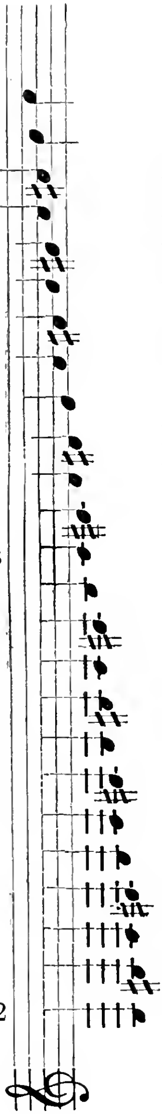
Tempered Intonation of Musical Vibrations.



Keynote.	Vibrations. n.	Log. n.	3 Log. n.
2 C	132·	2·1205739	6·3617217
B	124·591	2·0954867	6·2864601
A♯	117·598	2·0704000	6·2112000
A	110·998	2·0453153	6·1359459
G♯	104·768	2·0202286	6·0606858
G	98·888	1·9951436	5·9854308
F♯	93·338	1·9700586	5·9101755
F	88·099	1 9449710	5·8349130
E	83·152	1·9198727	5·7586181
D♯	78·488	1·8948033	5·6844099
D	74·082	1·8697127	5·6091381
C♯	69·923	1·8446201	5·5338603
1 C	66·	1·8195439	5·4586317
B	62·295	1·7944532	5·3833696
A♯	58·799	1·7693699	5·3081097
A	55·499	1·7442852	5·2328556
G♯	52·384	1·7191987	5·1575861
G	49·444	1·6941136	5·0823408
F♯	46·669	1·6690285	5·0070855
F	44·049	1·6439361	4·9318083
E	41·576	1·6187487	4·8562461
D♯	39·244	1·5937733	4·7813199
D	37·041	1·5686827	4·7060481
C♯	34·961	1·5435838	4·6307514
0 C	33·	1·5185139	4·5555417

Table IV.

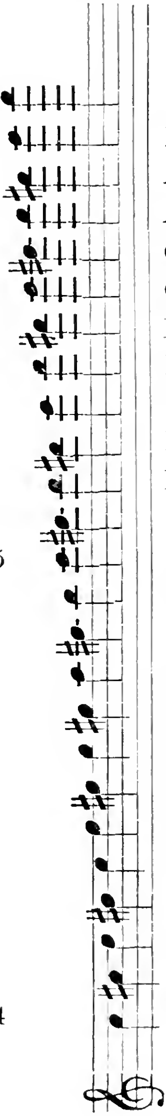
Tempered Intonation of Musical Vibrations.



Keynote.		Vibrations. n.	Log. n.	3 Log. n.
4	C	528·	2·7226339	8·1679017
	B	498·365	2·6975480	8·0926440
	A♯	470·395	2·6724722	8·0173866
	A	443·993	2·6473764	7·9421292
	G♯	419·097	2·6222905	7·8668715
	G	395·552	2·5972047	7·7916141
	F♯	373·352	2·5721189	7·7163567
	F	352·398	2·5470330	7·6410990
	E	332·611	2·5219472	7·5658416
	D♯	313·951	2·4968614	7·4905832
	D	296·330	2·4717755	7·4153265
	C♯	279·602	2·4477897	7·3400691
3	C	264·	2·4216039	7·2648117
	B	249·182	2·3965167	7·1895501
	A♯	235·197	2·3714319	7·1142957
	A	221·997	2·3463471	7·0390413
	G♯	209·537	2·3212400	6·9637200
	G	197·776	2·2961736	6·8885208
	F♯	186·676	2·2710885	6·8132655
	F	176·199	2·2460035	6·7380105
	E	166·305	2·2209053	6·6627159
	D♯	156·975	2·1958305	6·5874915
	D	148·165	2·1707457	6·5122371
	C♯	139·846	2·1456501	6·4369503
2	C	132·	2·1205739	6·3617217

Table V.

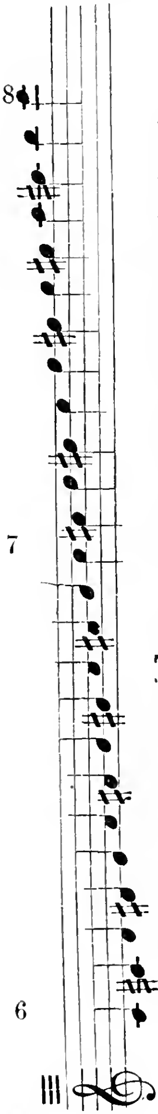
Tempered Intonation of Musical Vibrations.



Keynote.		Vibrations. n.	Log. n.	3 Log. n.
6	C	2112·	3·3246939	9·9740817
	B	1993·46	3·2996076	9·8988228
	A♯	1881·58	3·2745227	9·8235681
	A	1775·97	3·2494356	9·7483068
	G♯	1676·30	3·2243517	9·6730551
	G	1582·21	3·1992641	9·5977923
	F♯	1493·41	3·1741790	9·5225370
	F	1409·59	3·1490928	9·4472784
	E	1330·44	3·1239953	9·3719859
	D♯	1255·80	3·0989205	9·2967615
	D	1185·32	3·0738356	9·2215068
	C♯	1118·77	3·0487408	9·1462224
5	C	1056·	3·0236639	9·0709917
	B	996·730	2·9985775	8·9957325
	A♯	940·780	2·9734881	8·9204643
	A	887·986	2·9484061	8·8452183
	G♯	838·148	2·9231707	8·7695121
	G	791·106	2·8982347	8·6947041
	F♯	746·704	2·8731485	8·6194455
	F	704·796	2·8480634	8·5441902
	E	665·222	2·8229666	8 4688998
	D♯	627·902	2·7978919	8·3936757
	D	592·660	2·7728056	8·3184168
	C♯	559·384	2·7477100	8·2431390
4	C	528·	2·7226339	8·1679017

Table VI.

Tempered Intonation of Musical Vibrations.



Keynote. 3 Octaves above.		Vibrations. n.	Log. n.	3 Log. n.
8	C	8448·	3·9267539	11·7802617
	B	7973·84	3·9016675	11·7050025
	A♯	7526·32	3·8765827	11·6297481
	A	7103·88	3·8514957	11·5544871
	G♯	6705·20	3·8264119	11·4792351
	G	6328·84	3·8013241	11·4039723
	F♯	5973·64	3·7762390	11·3287170
	F	5638 36	3·7511528	11·2534584
	E	5321·76	3·7260553	11·1781659
	D♯	5023·20	3·7009805	11·1029415
	D	4741·28	3·6758957	11·0276971
	C♯	4475·08	3·6508008	10·9524024
7	C	4224·	3·6257239	10·8771717
	B	3986·92	3·6006375	10·8019125
	A♯	3763·12	3·5755481	10·7266443
	A	3551·94	3·5504656	10·6513068
	G♯	3352·59	3·5253804	10·5761412
	G	3164·42	3·5002941	10·5008823
	F♯	2986·82	3·4752090	10·4256270
	F	2819·18	3·4501228	10·3503684
	E	2660·89	3·4250253	10·2750759
	D♯	2511·61	3·3999522	10·1998566
	D	2370·64	3·3748656	10·1245968
	C♯	2237·54	3·3497708	10·0493124
6	C	2112·	3·3246939	9·9740817

The weight of bells is proportionate inversely to the cube of the vibrations per second; also the weight of the whole peal of any number of bells is inversely proportionate to the cube of the vibrations of the tenor. The fourth columns contain the logarithms of the cubes of the vibrations, which subtracted from the logarithm of a certain coefficient, depending upon the adopted *timbre* of the bell or peal, gives the logarithm for the required weight.

Figure 2 of the illustrations represents the curve of vibrations extending through eight octaves within the limit of the tables III to VI.

The science of acoustics has now brought the art of bellfounding under perfect control, so that bells can now be cast not only with correct pitch of tone but also with any desired quality of *timbre*, which is of considerable importance. A peal of bells may be good in pitch of tone, but a discordant *timbre* may make the ringing detestable to sensitive musical ears, which is often the case.

The difference of *timbre* is caused by different *upper partials*, and when these partials consist of consonant tones the sound is agreeable to the ear, but when of discordant tones or noise, as is often the case, particularly in bells, the sound is very disagreeable to sensitive musical ears and sometimes causes melancholiness. The *upper partials* are by-tones to the ground note, and are caused by the inertia of the vibrating body. The subject of *upper partials* is very extensive and intricate, and would require a special article for elucidation.

The tables III to VI will also answer for tempered intonation of all kinds of musical instruments.

(To be continued.)

Extinction of Fire by Steam.—The *Genie Civil* proposes, for the rapid extinction of fires in theatres, to have always in readiness high-pressure boilers in operation during the representations. These boilers should communicate with steam pipes opening at places which are most exposed to danger. By an ingenious contrivance, the heat, which would be produced by a fire breaking out, could be made to give vent to the steam, which would thus automatically arrest the ravages of the flames before they had time to gain much headway. The principle of extinguishing flames by steam was proposed by Abbé Moigno about thirty years ago.—*Les Mondes.* C.

THE MEARS CHLORINATION PROCESS.

By Wilkins U. Greene, Ph.B.

[A paper read at the Stated Meeting of the Franklin Institute, March 15, 1882.]

Gold was first discovered about the twenty-seventh or the twenty-eighth century before the Christian era. It occurs in three classes of deposits: 1st. Placer, formed by the action of water and frost on mountain sides, containing auriferous quartz veins. 2d. Segregated veins in metamorphic rocks. 3d. Fissure veins, where it is mingled with ores of iron, lead, silver, etc.

The extraction of gold from its ores is commonly effected in three ways, viz.: Smelting, amalgamation and chlorination, depending primarily upon the character and value of the ore.

The latter method, which has been hitherto chiefly known as the Plattner process, consists briefly in the treatment of properly roasted ore with chlorine gas.

The apparatus consists of a rectangular or cylindrical box, with a cover, which can be luted down; the roasted ore is placed on a false bottom and the chlorine allowed to percolate through the mass from the bottom; when the chlorine has reached the top, the cover is luted down and left for from fifteen to forty hours, in order to allow the gold in the ore to be converted into the chloride which is soluble in water; the gas left in the apparatus, after treatment, is practically thrown away, increasing the cost of working.

Upon treating the ore with water and filtering a solution is obtained which may contain 90 per cent. of the gold in the ore; an addition of ferrous sulphate now reduces the gold, which appears as a dark powder; this is collected and melted into a button of very fine bullion.

The Mears Process of chlorination is based upon the use of the gas under pressure.

The advantages attendant upon this modification, demonstrated on a working scale, are quicker work, larger percentage of extraction, no practical waste of gas and consequently less cost.

The apparatus used in this process is as follows: Chlorine gas is evolved in the generator *A* from a mixture of common salt, binoxide of manganese and sulphuric acid, in proportions of about one part of

manganese, two parts of salt and three parts of sulphuric acid; or the gas may be produced by chlorinated lime (commonly known as bleaching powder) and sulphuric acid, the choice depending on the price and facility of transportation.

The reactions are:

$$MnO_2 + 2NaCl + 3H_2SO_4 = MnSO_4 + NaHSO_4 + 2H_2O + Cl_2.$$

$$*(CaClO)_2CaCl_2 + 2H_2SO_4 = 2CaSO_4 + 2H_2O + Cl_4.$$

The salt and manganese binoxide are mixed together and introduced into the generator through an opening provided with a cover and clamp; a small quantity of water and the acid are added through the funnel, and the materials mixed by means of a stirrer. The gas passes from the generator through a wash-bottle containing pure water, which absorbs any hydrochloric acid which may be formed; it then enters the gasometer.

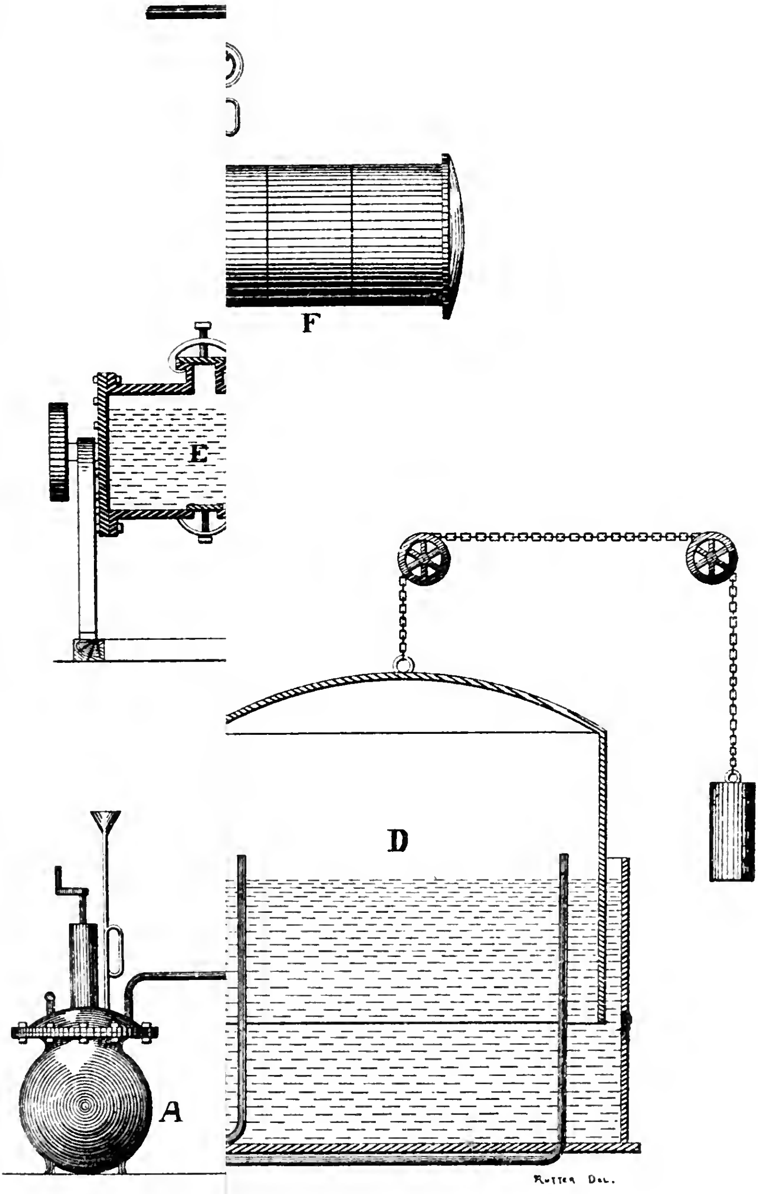
A pump *H* with its connections forces the gas into a receiver *F*, which stores an amount of gas under pressure of say, 50 pounds, as indicated by the attached gauge.

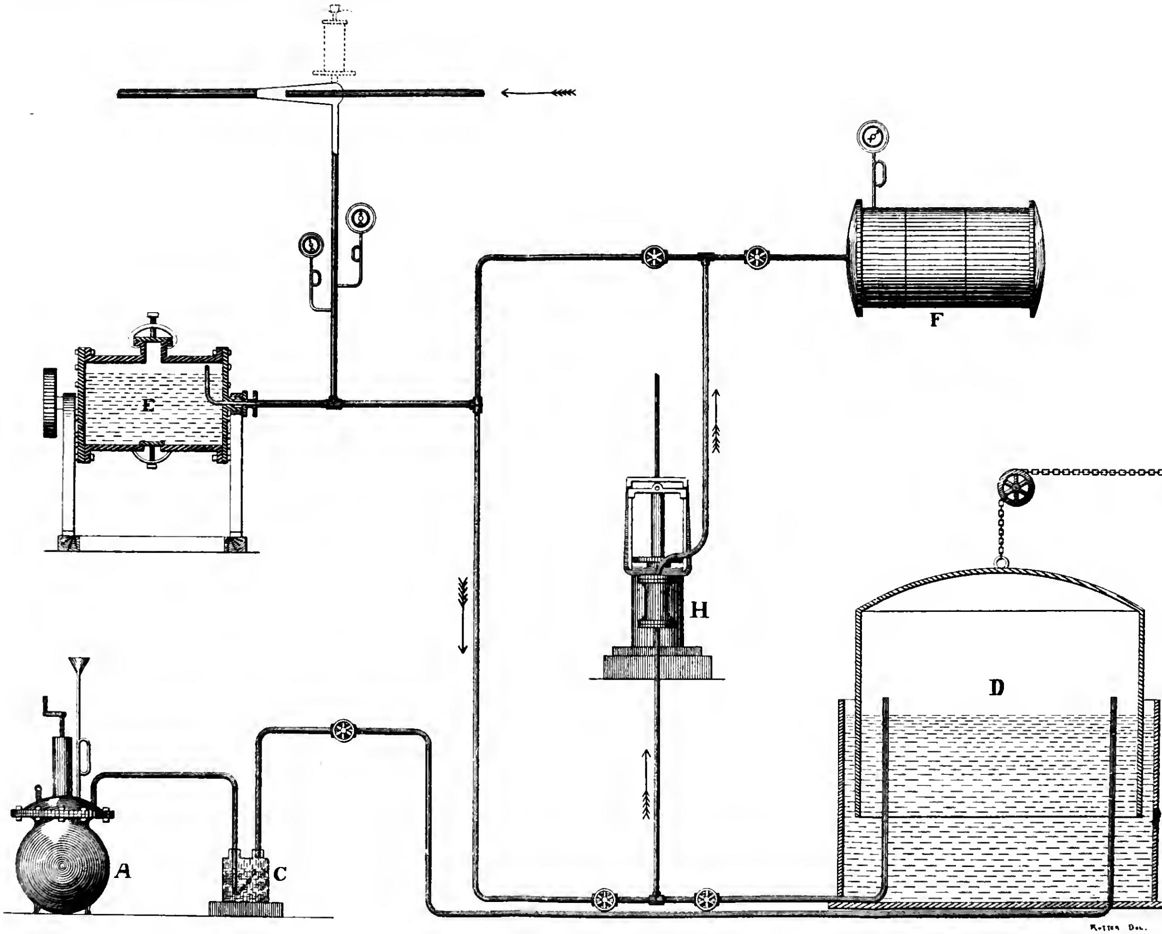
The chlorinator *E*, which receives the charge of ore, is an iron barrel revolving horizontally upon trunions. A one ton chlorinator is 42 inches in diameter and 54 inches in length, and makes 8 to 10 revolutions per minute. Like all the apparatus exposed to the gas, it is lined with lead; this lining has attached a series of ridges which assist the mixing of the charge; it also has a pocket of lead which is used when chlorine is produced by means of chlorinated lime.

The convex surface of the chlorinator has a charging hole, central between the trunions, and opposite is a man-hole. Through one of the trunions passes the goose-neck or pipe for the entrance of chlorine—it passes through a glass stuffing box, packed with asbestos, and held in position with a brass gland; inside it makes a vertical turn, and near the top a short turn in the direction of revolution; a branch pipe carries pressure and vacuum gauges and may be connected with a water column exhaust or pump.

Filtering vessels of iron, lined with lead, provided with perforated false bottoms of slate or tiles, upon which is placed quartz sand of different degrees of fineness, the upper layer being of finest sand; these receive the mass from the chlorinators.

* It is not certain that this reaction is so simple. The resulting product probably contains hypochlorous acid.


F
E
D
A
Rutter Del.


E
F
H
D
A
C
Rotter Del.

The filtered liquid then passes to the precipitating tank, and after treatment with the precipitant passes into the settlers. The operation is as follows:

The sulphurets, concentrated or not, are first roasted carefully to a dead or sweet roast.

The choice of a furnace is an open matter. It is found that the continuous feeding and discharging furnace is not sure to give a roast as required for chlorination—the form generally used is the reverberatory, with one or more hearths. After roasting, the ore is cooled, the requisite charge is introduced into the chlorinator through a hopper, with a quantity of water; after clamping down the cover of the chlorinator a vacuum is produced, with the water column or pump, in order that the gas may not be diluted with air. The chlorinator is then made to revolve; the proper valves are opened, all the others being closed, and the chlorine enters until the required pressure is reached. The charge being thoroughly mixed, by means of the ridges, rapidly absorbs the gas by the formation of chlorides of gold, and of the other metals which may exist in the roasted ore and may necessitate a second communication with the receiver.

At the end of from one to three hours the excess of gas is allowed to flow back into the gasholder, through other values shown in plate.

The chlorinator is now discharged into a trough connecting with one of the filters, over which the mass spreads to a depth of 3 to 4 inches. A quantity of wash-water is now let into the filter from a hose, and meanwhile the chlorinator receives a new charge. The filtrate and washings go to the precipitating tank where, after blowing a jet of steam or air through the liquid, in order to eliminate as much as possible of the chlorine gas contained in it, the presence of which would necessitate a larger use of the precipitant, a small quantity of a freshly prepared solution of ferrous sulphate (made by treating scrap iron with sulphuric acid) precipitates the gold as a dark-brown powder of extreme fineness. Large wooden settlers receive the contents of the tank for 12 hours alternately.

The settlers may be cleaned at long intervals, and the cement gold is then dried, smelted and cast into ingots.

The process, by careful working, extracts from 96 to 99 per cent. of the gold contained in the ore, varying in time and pressure with the coarse or fine nature of the gold and the amount of other soluble substances the ore may contain. The time consumed in the operations

varies from 15 minutes to $3\frac{1}{2}$ hours and the pressure from 20 to 40 pounds.

The usual precipitant employed to throw down the gold in metallic conditions, as already mentioned, is the ferrous sulphate. Numerous other reagents or substances may be used, as subchloride of arsenic, sulphurous acid, sulphuretted—hydrogen, phosphorus; also, coal, saw-dust, etc.

A patent has been issued to W. M. Davis, of Philadelphia, for the method of precipitating gold from its solution by allowing the same to pass through barrels of charcoal. The gold deposited on the carbon is subsequently obtained by calcination.

Mr. Davis had, previous to the issue of his patent, purchased the right to use the Mears Chlorination Process in North Carolina.

This chlorination process is especially adapted to gold ores, but ore containing gold and silver may be wrought and the silver extracted. This is accomplished by making a chloridizing roast, by the addition of a quantity of common salt at the end of the roast which converts the silver into the chloride, the process is then carried on as if no silver were present until the gold has been leached out of the ore; then a solution of hyposulphite of lime is introduced into the filter which dissolves out the silver, which is afterwards precipitated by sulphide of lime.

The question is asked whether the workmen are not affected unpleasantly by the gas? They are, if they breathe too much of it, but an apparatus can be so constructed that the air in the working-room can be kept comparatively free from the gas.

A long box is constructed, which is suspended near the ceiling, terminating on the outside of the building. At the end of this box is a powerful jet of steam or air, which causes a vacuum in the box and produces a constant draught upwards in the room.

The cost of the process depends on the price of labor, fuel, etc., the cost of treating a ton of ore varying from $1 to $3, exclusive of the roasting.

Works of fifty tons per day capacity, including best machinery, with steam-power for crushing, pulverizing, roasting, chlorinating and reducing to bullion, cost from $20,000 to $30,000.

Chlorination works, capable of handling ten tons per day of concentrated or selected sulphurets, can be attached to a stamp mill where power and pulverizing machinery are already in use, for an extra out-

lay of from $3000 to $5000, which will provide two chlorinators and all necessary filters, precipitating tanks, a retort and gas-holder, etc.

	Roasting.	Chlorination.			Results per net ton.		
	Time.	Time.	Pres.	Extracted.	Tailings.	Fire assay.	Dif.+or—
1.	6 hrs.	2 hrs.	35 lbs.	$58.55	$1.24	$62.01	+$2.22
2.		$1\frac{3}{4}$ hrs.	25 lbs.	20.00	.41	21.43	+ 1.02
3.	10 hrs.	3 hrs.	25 lbs.	15.58	1.13	16.21	— .50
4.	4 hrs.	1 hr.	25 lbs.	18.98	.34	18.60	— .72
5.	8 hrs.	3 hrs.	40 lbs.	48.77	.83	50.32	— .72
6.	10 hrs.	3 hrs.	25 lbs.	41.11	.41	42.37	— .85

ANALYSES.

	1	2	3	4	5	6
Silica,	10·26	72·50	11·11	72·67	29·73	18·38
				Pyrite.		
Sulphur,	41·81	15·10	47·67	1·99	25·23	35·10
Iron,	37·23	12·25	40·06	5·09	21·48	37·00
Copper,		·05	·59		2·03	
Lime,					4·06	1·60
Total,	89·30*	99·90	99·43	79·75*	62·70*	92·08*

1. Bunker Hill, Cal.
2. Boulder Co., Col.
3. Bob-tail, Col.
4. Nova Scotia.
5. Colorado Ore.
6. Plumas-National, Cal.

Injurious Elements of Illuminating Gas.—M. Pobek, of Breslau, finds that the chief poisonous agent in illuminating gas is carbonic oxide. In some cases, when the gas traverses a stratum of ground which is not yet saturated, it deposits the hydrocarburets which give it its characteristic odor and then diffuses itself in dwellings without its presence being perceived. In such cases the danger of explosion is added to that of poisoning. Explosions are comparatively rare, because the definite proportions which are required for an explosive mixture are not present. When the gas is imperfectly burnt, as in heating apparatus, there is an excess of moisture which is injurious to health.—*Chron. Industr.* C.

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* Incomplete analysis.

ACTION OF CHARCOAL UPON A SOLUTION OF GOLD CHLORIDE.

By Prof. George A. Koenig.

Among the substances which decompose gold solutions, the text-books—and, as far as I could find, the special literature—do not mention charcoal. This property of charcoal has become the subject of a United States patent, claiming that by filtering liquids containing in solution gold and certain metallic salts, the gold alone would be precipitated upon the charcoal, and none of the other metals. In the spring of 1880 my attention was drawn to this subject, and, as the fact appeared unquestionable, it became of some interest to ascertain the reactions involved.

The following possibilities suggested themselves:

1. Gold might be precipitated by the alkaline carbonates of the ash mixed with the charcoal from the charring process.

2. Gases condensed in the coal might act as reducing agents.

3. The action might be physical only, belonging to the so-called catalytic phenomena.

4. Carbon might be oxidized by auric chloride and water, either to carbon monoxide or dioxide.

Gold hexachloride was prepared as nearly free from uncombined chlorine as several evaporations to dryness could make it.

Charcoal was broken into pieces, and, by sifting, assorted to an average diameter of about $\frac{3}{32}$ of an inch. It was then digested with hydrochloric and hydrofluoric acids for 12 hours, and washed first with dilute acid, then with distilled water until the latter ceased to act upon blue litmus. After drying, the charcoal was kept at a full red heat for one hour in a closed crucible. Any action produced by this purified material upon gold solution could not be ascribed to inorganic constituents.

First Experiment.—30 grammes of the charcoal were placed into a half-litre flask, and the latter filled one-half with water. Heat being now applied, the contents of the flask were kept boiling for 30 minutes, under replacement of the evaporating water. Condensed or occluded gases were now presumably expelled, and a measured aqueous solution of gold chloride, corresponding to 1·452 grammes of metallic gold, was added, whilst the flask was furnished with a doubly perfo-

rated cork, and left at ordinary temperature for 2 hours, when the yellow color of the liquid had disappeared and the charcoal become coated with gold. Having now connected the flask on one side with a Geissler potash bulb, filled with aqueous barium hydrate, and on the other with a gasometer, containing pure air, the flask was again brought to boiling, while a slow current of air passed into the flask, the air passing through several U tubes containing sodium hydrate. A turbidity in the barium hydrate became visible at once, and after 15 minutes of boiling the precipitate of barium carbonate was determined as barium sulphate with the usual precautions.

$$BaSO_4 = 0{\cdot}070 \text{ gr.} = 0{\cdot}0036 \text{ C.}$$

Now, according to the equation

$$(AuCl_6 + 3H_2O)_2 + C_3 = Au_2 + (HCl)_{12} + (CO_2)_3$$

we have

$$784 \text{ Au} : 36 \text{ C} = 1{\cdot}452 \text{ gr. Au} : 0{\cdot}0666 \text{ C};$$

that is to say, that only about $\frac{1}{20}$ of the gold was precipitated by the chemical action of charcoal.

A closer examination of the charcoal showed a marked difference. Some pieces had a brilliant compact coating of gold, others a dull porous coating, and many none at all.

Second Experiment.—Lampblack was strongly heated in a closed crucible to redness. It was then washed with hot water and again dried. If the action of the charcoal were chemical, then lampblack should act more readily. In order to test this assumption 0·2 gramme of gold, as chloride, was dissolved in 100 cc. of water and 6 mgr. of the above lampblack added. A disengagement of gas was noticed at the boiling heat, and also a slight precipitation of gold. Boiling was kept up for 2 hours, when the liquid was still colored from gold chloride. Again 6 mgr. of lampblack was added and boiled for 3 hours longer with a condenser attached. The liquid was now filtered and still yellow in color, while the precipitated gold was largely mixed with lampblack. After ignition the gold weighed 0·0495 gramme, or nearly $\frac{1}{5}$ of the quantity contained in the liquid.

These experiments do not cover the entire field of inquiry upon the subject, but they seem to indicate a parallel physical and chemical action, the former depending upon the surface and capillary condition of the charcoal, lampblack not acting physically at all, the latter depending upon a combustion of carbon into carbon dioxide.

University of Pennsylvania, March, 1882.

Book Notices.

PRACTICAL HINTS ON MILL BUILDING. By R. James Abernathey, Moline, Ill. London, Eng., 1880. 8vo.

This treatise, though general in name, is confined to flour milling, commencing with reminiscences of the older modes, which, if very slow, were certainly in several respects safer than the later and improved processes. The art of flour milling is much indebted to Oliver Evans for various improvements ; if his plans were simple and crude they gave a new life to the antique style of grinding grain which seemed to have slumbered for ages. In those olden times—truly the palmy days of the millwright—everything which could be so constructed, was made of wood—penstock, waterwheel, windwheel, horizontal and upright main shafts, cogwheels, pinions and pullies, while belting was almost unknown. Several interesting extracts are given from the *Millwrights' Guide*, written by Oliver Evans, a work, the existence of which is probably unknown to many of our readers.

For unpracticed mechanics, Mr. Abernathey furnishes simple and useful general directions for arranging shafting and cogwheels, all iron or having wooden teeth, pullies, the ironing, setting and balancing of stones, making curbs, elevators, spouting, etc. The proper modes and machines for cleaning wheat, remedying specks in flour, the making, speed and clothing of bolting reels, etc., are also concisely explained. While mentioning the various kinds of shafting and cogwheels, the author remarks that the main upright shaft "is a nuisance anyhow," even if properly set, which is a rare case. He at the same time speaks more favorably of hard-wood boxes for shafting than might have been expected from a mill treatise of recent date. He devotes considerable attention to turbines ; states that overshot, breast, or undershot water-wheels are now rarely introduced, and he prefers not to discuss the steam engine as a mill-motor, but to leave that to machinists.

An important portion of the volume comprises directions and detailed tables in regard to the pitch and speed of cogwheels, and the velocity and width of single leather belts for certain amounts of power. The author "does not assume to know" whether rubber belts will transmit as much power as those made of leather, but "would risk either"—though preferring leather. This is a mode of writing rather

too indefinite, for one who ought to know that there is much more tendency in rubber belts to slip on pullies than is the case with leather; independent of any other disadvantage. There are also tables appended for the thickness of shafts required for power named.

The second part of this book is the most important, treating of the furrowing of buhrs, middlings-purifiers, the new roller process, gradual reduction, and the Hungarian milling system. There are many valuable facts here set forth, in concise language, accompanied by plates and diagrams, in the text, of the various newer flouring machines and arrangements (with some omissions, however), different forms of rollers, etc. There are, in addition, valuable information and data, too numerous to mention, relating to other subjects connected with flouring mills. Mr. Abernathey gives excellent advice for the management of steam boilers, chiefly with the view to avoid their explosion; but he scarcely alludes to the great danger from explosion of flour-dust, or to the general increase of the fire-risk of flouring mills during the past few years. Notice of the best means of prevention and protection against such danger would have been undoubtedly acceptable. The work may be designated as practical, but not exhaustive. S. H. N.

TEXT-BOOK OF EXPERIMENTAL ORGANIC CHEMISTRY. By H. Chapman Jones. D. Van Nostrand. New York: 1881.

This little book, which is intended more as a guide to laboratory experiments than as a text-book for the classroom, appears to fulfill a want in this direction in a satisfactory manner. The student is led through an easy and simple course of experiments, such as will give him an insight into some of the beauties of organic chemistry. The experiments to be performed are clearly described and explained, and the text is written in an interesting, but strictly scientific style. We feel sure that many students will enjoy and profit by a careful study of the book. R. H.

SEWER GASES, THEIR NATURE AND ORIGIN; AND HOW TO PROTECT OUR DWELLINGS. By Adolfo de Varona, M.D. Second Edition, Revised and Enlarged. D. Van Nostrand. New York: 1882.

This little book can scarcely claim any originality either in facts or in treatment of the subjects presented. Yet short, unpretentious, popular essays on sanitary subjects, published in the cheap form, now

becoming more common, are an important means of arousing the people to some degree of attention to the avoidable causes of disease and the proper way of preventing them.

Although the author appears to consider the first part of the book, which treats of sewer gas and sewerage, as the most important, he is evidently much better acquainted with the subjects of ventilation and disinfection which are considered in the latter part, and he would, perhaps, have been wiser to have confined his essay entirely to these.

We will merely allude to the rather numerous errors, both in statement and in orthography, to be found in the first part of the book. There are not a few statements in regard to the composition and nature of sewer gas which a chemist certainly cannot endorse, several of which are also quite contradictory. While considerable correct information is given in this book, we must consider it on the whole rather unsatisfactory as a Science Primer. R. H.

REPORT OF THE CHIEF SIGNAL OFFICER FOR THE YEAR 1881.

The annual report of the Chief Signal Officer of the U. S. Army, to the Secretary of War, shows that both in the Military and in the Meteorological department there has been a steady and healthy growth, the equipments in all branches having been improved by additions which have been suggested by study and experience. In order to bring the service into active sympathy and co-operation with the ablest scientific institutions, the National Academy of Sciences has appointed an advisory committee of specialists. A permanent school of instruction has been established at Fort Meyer, in order to qualify the corps of observers in the duties of every department, and to raise the standard of service. The work has been more thoroughly systematized. New instructions for observers and improved forms for recording and preserving Meteorological data have been prepared. There has been a gradual extension and increase in the variety of forecasts, for the benefit of the various agricultural, manufacturing and commercial interests in all parts of the Union, with special forecasts of hot and cold waves, "northers," frosts, floods and ice-gorges. Important investigations of thermometric and barometric standards have been made, new constants computed and new tables constructed. Arrangements have been made for original investigations of atmospheric electricity, wind-force and solar energy, and for co-operation in the solution

of important physical problems. Two expeditions have been equipped for the Arctic regions, to share in the work marked out by the International conference. A system of stations has been established in Alaska, and arrangements have been made for organizing weather services for the Pacific coast and for separate States. The telegraphic service has been increased by a value of more than $34,000 per annum, without any additional cost to the government, and there is a prospect of further economy which will yield an additional reduction of $75,000.

This is only a partial enumeration of the subjects which have claimed the attention of the Bureau, but it is sufficient to show that our country is still without a rival in the variety, amount and practical advantages of its Weather Service. C.

Incandescent Electric Lights, with Particular Reference to the Edison's Lamps at the Paris Exposition. By Compte Th. du Moncel and Wm. Henry Preece. To which is added "The Economy of the Electric Light by Incandescence," by John H. Howell; and on the "Steadiness of the Electric Current," by C. W. Siemens. New York: D. Van Nostrand. 1882.

No. 57 of Van Nostrand's Science Series, on Incandescent Electric Lighting, is received, and, like most of its predecessors, is filled with interesting matter on the subject in hand.

In this little book the question is discussed by four different authors. Two of these, Mr. Siemens and Mr. Howell, bring their figures and experiments with them to justify their work and make good their assertions. The other two give good descriptions, in rose-color, of what they hope for the light rather than what has been fully demonstrated. The only feature that detracts from it, as a scientific paper, is a faint suspicion of an advertisement, and even with this it is a welcome addition to our electrical literature. Especially is this the case with the articles of Messrs. Siemens and Howell. The former giving the results of his experiments in the duplicate winding of coils for field magnets. These results are tabulated, so as to show, in compact form, the efficiency of the new system as compared with the old. And the latter giving his conclusions as to the cost of incandescent electric lighting, and showing the methods adopted to arrive at those conclusions. Both of these papers have been prepared with much care, and fully merit the consideration which they will undoubtedly receive.

Mr. Siemens demonstrates the possibility of increasing the efficiency of the dynamo machine from 45 to 53 per cent., a most desirable attainment; and when to this is added the greater steadiness of the current produced we see the value of the line of improvement which these experiments suggest. It may be said that the arc lamp should be so constructed as to present at all times an unvarying resistance, and that then the work of the dynamo would be uniform and currents regular in the present form of machine. Unfortunately, however, this is not the case. They have not been so made, and until they are the present relief from current fluctuations will be highly appreciated by those interested in electric lighting.

It is but fair to say, however, that Mr. Siemens' experiments were made with a comparatively small machine, and that the resistances in the outer circuit presented only slight fluctuations. What the result would be in a long circuit—such, for instance, as a Brush circuit—of forty arc lamps, where the resistance varies, say from 80 ohms, when all the lamps are drawing full arc, down to 40, when a large number of lamps feed simultaneously, can only be conjectured.

In Mr. Howell's paper we have the result of the investigations of an unbiased expert on whose figures we can rely, and if we find that after computing interest on plant, cost of maintenance, attendance, etc., there is still a margin left under the cost of gas, we can safely engage in incandescent lighting. Unfortunately, however, his figures are not reassuring. Where the necessary power is already employed during the day, for other purposes, it may be feasible. But where the power must be supplied on purpose it is very doubtful if even at ten lights of 16-candle power, per H.P. consumed, the operation would be satisfactory, financially. Much less would it be so with the number dropping down to six or seven per horse-power.

With the system worked up so completely, and all the appliances supplied for making it convenient and ornamental, it seems a pity that the cost of the power to produce it should debar us from its use, and it is to be hoped that the thumb-screw of invention can be so applied to some other part of nature's organism as to extort a power sufficiently cheap to make this admirable system a practical success.

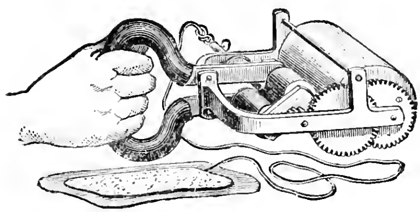
N. H. E.

AN INSTRUMENT FOR ELECTRO-MASSAGE.

At the last stated meeting of the Institute the Secretary, among other novelties, exhibited and described the ingenious Electro-massage instrument of Dr. John Butler, of New York, the appearance of which is shown in the accompanying illustration.

The object sought to be accomplished by this invention is to combine, by the use of one instrument, the several operations of massage (manipulation, or friction by the hands on the limbs and joints) and electrization; for as both of these procedures are found necessary or advantageous in certain muscular, articular and nervous disorders, and are usually applied successively, often to the great fatigue and discomfort of the person operated on, the desirability of devising an apparatus by which these two procedures would be accomplished at once is obvious.

The inventor of this apparatus, in watching the operation of



manipulation, conceived the idea that if the mechanical motion used in rubbing the patient could be made to generate an electrical current, which should be transmitted to the affected part while it was being manipulated, the requirements of the case would be met. Following out his idea, he devised the instrument here referred to, which appears to answer its intended purpose very well.

The instrument, as will be understood by consulting the accompanying cut, consists of a hollow metallic roller, covered with chamois leather, an electro-magnet, and a permanent magnet, the whole set in a strong frame, which holds it together. The roller acts on one of the electrodes, and is likewise the driving piston of the apparatus, communicating its motion, by means of connected gearing, to the electro-magnet, causing the poles of the latter to revolve opposite to those of the permanent magnet. The rounded portion of the latter, which is

flared for greater convenience, forms the handle by which the instrument is moved to and fro over the part of the body to be treated.

The proportions of the gearing are such that each revolution of the roller causes the electro-magnet to make twenty-five revolutions. The current thus induced is interrupted at each revolution by a break-piece. The instrument gives a current sufficiently strong for the purposes for which it is intended to be used.

To complete the circuit a flexible metallic disk, likewise covered with chamois, is connected through an insulated wire to the binding post shown in the cut.

In using the apparatus both electrodes are moistened to increase their conducting power, the hollow roller being filled with warm water to render its application agreeable, and both are brought in contact with the body of the patient. As the moistened roller is moved with gentle or vigorous pressure, as the case may require, over the surface of the body, the current is transmitted, by the apparatus, through the part over which the roller is caused to move. By shifting the position of the armature of the permanent magnet the strength of the current can be regulated at will.

RECENT IMPROVEMENTS IN THE MECHANIC ARTS.

Lighting Gas by Electricity.—A novel electric gas-lighter consists of two positively operated movable electrodes arranged to meet over the gas-orifice and then recede out of reach of the flame. They are operated by the turning on and off of the gas, by the ordinary horizontal cock of the gas-burner. One of the electrodes is rigidly secured to the rear end of the cock-spindle and is carried by the rotation of the latter through a vertical arc past the side of the burner. The other electrode is pivoted, near its lower end, to the side of the burner, and provided with a sector-pinion which engages with a similar pinion formed on the forward end of the cock, so that the motion of the cock will cause the latter electrode to be moved in the same manner as the former. The arrangement is such that the two electrodes move in opposite directions, passing each other when in line with the gas outlet, and falling back in opposite directions out of the flame. Small projecting fingers of platinum are secured to the ends of the electrodes and pass each other with a frictional contact, whereby the production of the electric spark is insured.

SELF-PROPELLING TORPEDOES.—In the recent experiments with the Lay torpedo, at the U. S. Government torpedo-station at Newport, R. I., a grave difficulty was encountered, in that the tendency of the liquid carbonic acid gas—which is used as the motive force for driving the torpedo—was to freeze, when suddenly expanded by being drawn off from the reservoir or flask for use. Artificial heat was, for a time, used to counteract this tendency of the liquefied gas to congeal when drawn from the flask, but with unsatisfactory results. It remained, however, for a retired physician of Hartford to happily solve this apparently insurmountable difficulty by the discovery of the fact that there was sufficient latent caloric in the sea-water, in which the torpedo-boat itself was immersed, to supply the heat necessary to prevent the congelation of the gas when expanding in the pipes between the flask and the engine. This was accomplished by running the connecting pipes between the flask and engine on the outside of the torpedo-boat, in direct contact with the sea-water.

MECHANICAL TELEPHONE.—This recent improvement provides a means—without the employment of a battery—for transmitting and reproducing sounds, loud, clear and distinct, at short or long distances as may be desired. It consists of a simple helix surrounding a soft-iron core, having no magnetic connection, and acted upon by a thin strip of iron connected with the north or south pole of one or more magnets. This strip vibrates in unison with the transmitting or receiving diaphragm by means of a felt cushion or other connecting medium. This construction, it is said, constitutes a magneto-electric machine or generator, whereby the voice itself produces the electric current by which the sounds are transmitted to and reproduced by a similar or corresponding instrument at the other end of the line, there being no current in the helix or on the line, excepting that so produced, and no other magnetism in the soft-iron core inside the former.

NEW ENGINE GOVERNOR.—The object of this improvement is to provide a governor for steam engines that will not require a change in the speed of the engine in order to bring about a change in the amount of steam admitted to the cylinder. It consists in the interposition, between the piston and the crank of any engine, of a hydraulic cushion which shall receive compression by the transmission of power through it to the crank. This compression is utilized to actuate the cut-off gear or throttle-valve.

New Method of Operating Telephone Exchange Apparatus.—Two or more automatic switches are provided, each constructed to allow any subscriber connected thereto to automatically connect his line with any other line upon the same automatic switch, and a line or lines from each automatic switch to a common manual switch. Suitable apparatus is provided at the manual switch for operating the automatic switches. This arrangemement enables any subscriber to connect his line either to any other subscriber's line of his automatic section, or to a line leading to the manual switch for connecting the subscriber's line with any other line-connection upon the manual switch.

Valve-Gear for Steam Engines.—This improvement in valve-gear comprises a steam or other engine employing a slide-valve and the usual inlet and exhaust ports, in which the valve has a stroke equal in length to that of the piston, and the longest axis of the port-opening under the valve is in the plane of the travel of the valve.

Washington, D. C. F. B. Brock.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

As we go to press, the American Society of Mechanical Engineers is holding its first regular meeting of the current year, in the Hall of the Institute, under the presidency of Prof. Robert H. Thurston, of the Stevens Institute. The meeting is fully attended and, from the number and character of the professional papers to be presented, promises to be the most important meeting which this young but flourishing Society has held. The programme provides for a session of three days from Wednesday, the 19th, to Friday, the 21st of April, inclusive.

For the first day's session, the programme provides for general business, professional papers and discussion in the morning and, for the afternoon, a memorial service in honor of the late Alexander L. Holley. Mr. James C. Bayles is named to pronounce a eulogium upon the deceased. In the evening, the Society is invited to a reception, in its honor, in the Academy of Fine Arts, by the citizens of Philadelphia.

The programme for the second day embraces an excursion on the Delaware river in the morning, with visits to such places of professional interest as the League Island Navy Yard, the grain elevators,

Wm. Cramp & Sons' shipyard, John Roach & Son's shipyard, etc. The evening is devoted to a subscription dinner at Horticultural Hall.

The third day's programme provides for strictly professional business, at morning, afternoon and evening sessions.

CORRESPONDENCE.

The following correspondence respecting the Panama Canal, received by the Secretary for presentation at the monthly meeting of the Institute, by courtesy of Prof. J. E. Nourse, may have some interest to many of the readers of the JOURNAL. W.

U. S. STEAMER "VANDALIA,"
HAVANA, CUBA, *March 1, 1882.*

HON. W. HUNT,
Sec'y Navy, Washington.

SIR:—It may be interesting to the Department to learn the results of my personal observations on the Isthmus of Panama, and of the changes that have occurred since my last visit eleven months ago.

The Canal Company has quietly been at work, preparing for the gigantic task before it. It has accomplished a large amount of work which I should term "surface" or preliminary work. Several of the best officers of the company have died since my last visit: notably, Messrs. Blanchet, Bionne and Sharpe, the latter Superintendent at Gatun. None of these gentlemen died of yellow fever, as reported. Messrs. Bionne and Blanchet died of the local fever of the country, want of suitable attention, and overwork and neglect of themselves. I heard it said here that Sharpe committed suicide; whether this is true or not I do not know.

A number of deaths among the inferior employees have occurred, but the number has been greatly exaggerated in the American newspapers. Of course a number of the white employees have been ill with Calentura, but the death rate has not been exceptionally great; which I consider remarkable, as my personal observation is that the French employees take little or no care of themselves, and eat and drink just as if they were at home in France, and poison themselves with vast quantities of absinthe.

I crossed the road to Panama, and with Mr. Alfred Razy, in charge of the works at Aspinwall, visited the proposed axis of the Canal near the Rio Mindi. I saw enough to convince me that, notwithstanding the reports to the contrary, a large amount of valuable work has been accomplished.

Whether as much has been done as would have been done had American engineers superintended, I cannot say. My own belief is that our people would have accomplished more and spent more money. The French engineers will work in their own way and take their own time. I am told that nothing important is done until it is sanctioned by the great minds in Europe. The work progresses steadily, but a work so gigantic as this Inter-oceanic Canal needs cautious work and careful expenditure of money at first, until the final plans and lines are well determined. The entire route has been cleared of trees and underbrush for a width of 300 yards. This is a work of no small magnitude in itself. Fifty miles of undergrowth cleared off in this region represents a deal of work. The trees and undergrowth have been partially burned off, and will probably all be burned off before the season ends; for, if left, the vegetation here is marvelously rapid and much of the work would have to be gone over again.

All along the line the Company has constructed stations and villages for its laborers; at Gatun these works are of an elaborate character. I think more money has been spent than is necessary for grading. Sidings and narrow-gauge rail tracks are also constructed to carry off the earth taken up by the excavators, which earth is to be dumped into the marsh near Boca-Chica, so as to be the foundation of a town.

The machinery brought from Europe is clumsy and comparatively antiquated, and I hear that much of the machinery will be made in the United States. A sub-contract with Messrs. Sleven & Co., of San Francisco, to commence excavating between the Mindi and Gatun, is reported.

Messrs. Razy and Hull, the officers of the Canal, were exceedingly polite to myself and officers, and offered every facility.

I am, sir, very respectfully, your obedient servant,

(Signed) R. W. MEADE,
Captain U. S. N.

A Long Span of Wire.—The longest span of wire in the world is used for a telegraph in India, over the River Kistnah, between Bezorah and Seetanagrum. It is more than 6000 feet long and is stretched between two hills, each of which has a height of 1200 feet. The only apparatus that was used for stretching the wire was a common anchor capstan.—*Der Techniker.*

Vienna Metropolitan Railway.—This enterprise will require an expenditure of about 12,000,000 francs ($2,400,000). The track will be principally laid upon elegant and solid viaducts and a part in tunnels. The funds are furnished by an English company, the works being directed by English engineers. After examining various systems in the United States, Germany, England and France the company has adopted Francq's French locomotive. Thus, while the French waste their time in discussions of various methods for relieving the crowded traffic of streets, other nations profit by their inventions and discoveries. The French invent, study and discuss, adding plan to plan and device to device, their neighbors act.—*Les Mondes.*

Electric Metallurgy.—Electricity is still too dear to be extensively employed in the mechanic arts, but it can be advantageously substituted for coal and heat in the reduction of zinc ores. The ordinary processes require an expenditure of about 70 or 80 francs ($14.00 or $16.00) per ton. Electricity may be employed in three different methods, which differ chiefly in the nature of the acid which is employed as a solvent. The ores do not require much preparation, the calamine need not be calcined and it is not even necessary to separate the lead or the calcareous gangues. The ores are placed in great basins, after being treated with sulphuric acid, where the sulphate of zinc is dissolved in water. The liquid passes through a series of basins where it deposits, in a metallic state, under the action of electricity, a part of its zinc and the liberated acid is used upon new supplies of ore. The lead, silver and other insoluble matters are collected in the residue and the iron, which is precipitated upon the lead anode, falls to the bottom of the basin. If the electricity is produced by steam power, the quantity of coal which is required for a given amount of zinc is almost precisely the same as would be required for the same amount of ore in the old methods. The treatment can be conducted at the mine, thus avoiding much of the expense of transportation. The plant is only about half as great as in distillation.—*Chron. Industr.*

Improved Mortar.—Sawdust is better than hair in protecting rough cast from peeling and scaling under the influence of frost and weather. The sawdust should be first dried and then thoroughly sifted, in order to remove the coarser particles. A mixture is then made of two parts sawdust, five parts sharp sand and one part cement, which should be thoroughly stirred together and then incorporated with two parts of lime.—*Der Techniker.* C.

Variations in the Velocity of Sound.—Prof. Mach, of the University of Prague, has experimented with sounds which are produced by electric sparks. The waves which are excited by two simultaneous sparks interfere, and the interferences are observed by the traces which they leave upon glass covered with lamp black. The velocity of wave propagation is greater than that of ordinary sound waves, but it diminishes in proportion as the waves separate from the point of excitement and tends towards the ordinary values.—*Soc. de Physique.* C.

Ocean Meteorology.—The study of ocean meteorology, which was first successfully undertaken by Lieut. Maury, has been greatly extended in France by M. Brault. His investigations were begun in 1869, upon the basis of exclusively French documents, and they were so successful that, in 1878, he received a prize from the French Exposition. His charts of the North Atlantic appeared in 1875 and were presented to the French Academy on the 6th of September. They contain 230,000 observations, both of the direction and of the intensity of the wind. The charts of the South Atlantic appeared in 1876, and those of the Indian and Pacific oceans in 1880. They contain 1,820,000 observations. One of these charts is especially noticeable, that of the summer isanemones or curves of equal wind-velocity. They are almost identical with the curve of mean isobars or mean atmospheric pressure. They introduce, for the first time, considerations of the force of the wind at the surface of the ocean, and throw light upon such points as the succession of winds, the ocean currents, the rainfall, the state of the sky and sea, the proportion of tempests and all the principal elements of nautical meteorology. — *Les Mondes.* C.

Introduction of the DuPuy System into Spain.—A successful trial of DuPuy's method of obtaining soft iron directly from the ore has been lately made in England, in the establishment of Lord Dudley, at Round Oak. It was witnessed by a Spanish engineer, representing one of the largest national works, with a view of introducing the system into Spain. It is expected that its introduction will be of great advantage to the iron industries of the Peninsula and that it will thoroughly supplant the old and barbarous methods of hand-puddling.—*Gaceto Industrial.* C.

Ventilation of the Mont Cenis Tunnel.—M. F. de Kossuth, Director-General of the mines of Cesena, has made a special study of the subject of artificial ventilation, in order to devise some remedy for the insufficient supply of air in the tunnel of Mont Cenis. His examination embraces the quantity of air required for good ventilation, examples of mines in which a sufficient supply is introduced by mechanical means, the laws of ventilation in subterranean galleries, the facilities for automatic ventilation, the quantities of injurious gas developed in the tunnel, the quantities which are required to dilute the deleterious gases produced by combustion in the locomotives, the time in which the air of the tunnel would become asphyxiating if ventilation ceased, the inconvenience of the measures which are now employed, and a demonstration of the efficacy of the plan which he proposes. He finds that 84 cubic metres (109·874 cubic yards) per second would be required and that it could be supplied by 224 horse-power. There is already a canal at Bardonnèche which supplies 800 litres (211·36 gallons) per second, with a fall of 42 metres (45·93 yards), which would yield a force of 448 horse-power. This force can be obtained without other cost than is required to maintain the necessary repairs.—*Ann. des Mines.* C.

Phosphor-Bronze Wire.—The experiments of Nystrom and Rothen show that phosphor-bronze wires have an electric conductibility about one-fifth as great as that of copper or one and a half times as great as that of iron. Bede has found that one kilometre (1093·633 yards) of phosphor-bronze wire, 2 millimetres (·0787 inch) in diameter, has a resistance of 28 ohms, while an iron wire of the same dimensions has a resistance of 40 ohms. A wire which is well hard-

ened at the drawing-plate has a tensile strength of 120 kilogrammes (264·55 pounds) per square millimetre and stretches only about one per cent. before breaking. A wire which is properly annealed stretches about 60 per cent., but the tensile strength is only about 40 kilogrammes per square millimetre. The rupture of a telegraphic or telephonic wire may cause accidents to men or houses in cities. Bede has shown that when a wire of phosphor-bronze breaks its elasticity brings the fragments towards the neighboring supports before they have time to do any injury. In Brussels a large number of telephonic lines been supplied with phosphor-bronze wires of $\frac{8}{10}$ millimetre (·0315 inch) in diameter. In Ghent nearly the whole telephonic network is laid with the same wires. This small diameter can be employed because the resistance of the wire to oxidation secures its durability. —*Ingen. Conseil.* C.

Electric Current Produced by Light.—M. P. Laur reports the following experiment. In a small dark chamber, with a movable shutter, a glass vessel with plain sides is placed, in which he pours a solution of 100 parts water, 15 parts common salt, 7 parts sulphate of copper; a porous vase filled with mercury is placed in this solution; two electrodes, one formed by a plate of platinum, another by a plate of sulphuret of silver, are inserted, the first into the mercury, the second into a cupric solution; these two electrodes are connected with a galvanometer, the apparatus is placed in the sun and the dark chamber shut; as soon as the circuit is closed the galvanometer needle turns in a direction which shows that the silver sulphuret is positive; when the needle comes to rest the shutter is opened and the needle is immediately repelled, soon coming to a new position of equilibrium; on closing the shutter again the needle slowly retrogrades towards its first position. When the needle is placed in the open air, if a cloud passes before the sun the movements of the needle show the variations of luminous intensity. The movements are attributed to the reduction of the silver sulphuret by the cupric proto-chloride, a reduction which takes place only under the action of the sun's rays. Similar photo-electric currents may be produced by other combinations of electrodes.—*Comptes Rendus.* C.

Repeating Piano.—In the French Electrical Exposition, J. Carpantier exhibited a repeating electrical apparatus which he called a Melograph. It is connected with a harmonium some yards distant, the keys of which are electrically connected with punches in the Melograph; these punches, when the electrical connection is completed, pierce a band of paper in accordance with the notes which are played. When the band is prepared, the Melograph can react upon the harmonium, making it repeat the air as often as may be desired. The inventor hopes to improve his instrument so as to give satisfactory reproductions of the most intricate improvisations.— *Chron. Industr.* C.

Restoration of Architectural Structures.—T. V. Parravicini severely criticizes the rage of restoration which has prevailed so largely during the last half-century. While much good may have resulted from the minute investigations and profound architectural studies to which they have given rise, he fears that, if the buildings continue to be treated as they have been, our grandchildren will be unable to form any idea of their original beauty. In many cases more has been done for the destruction of noble monuments of art than had been accomplished in the preceding ages of ignorance, barbarism and devastation. When the strange and fatal idea of restoration first arose, monumental archæology was still in its infancy and had not learned that the historic and artistic importance of a building depends wholly upon the authenticity of its various parts. The idea of the restorer implies the possibility of taking from a monument some part of its life, with the sole object of representing in the building the best times in its history, or giving it a unity of style which it never had, without any other guide than individual caprice. In past ages any suspicion of falsification was removed by the fact that builders had no knowledge of preceding styles; hence, when any repairs or changes were made, they necessarily followed the fashions of the time and thus maintained a truthfulness which should always characterize the highest excellence in art.—*Il Politecnico.* C.

Fish Culture in Germany.—The report of the Union of German fisheries states that during the last season 6,151,030 fish eggs have been fecundated artificially and the young fry have been distributed in the different rivers of the country. Among the eggs were 1,792,000 salmon from the Rhine, 295,000 California salmon imported from America, 183,500 trout of different species, 657,000 sea eels and 1,720,000 carp.—*Les Mondes.* C.

Franklin Institute.

HALL OF THE INSTITUTE, April 19, 1882.

The stated meeting of the Institute was held this evening at the usual hour, the President, Mr. Wm. P. Tatham, in the chair.

There were present 57 members and 17 visitors.

The minutes of the last meeting were read and approved.

Upon the approval of the minutes, Mr. William H. Parker moved—as a mark of respect to the American Society of Mechanical Engineers, now holding its sessions in the city, and to enable those members of the Institute who are also members of the Society to attend the reception to be given in its honor at the Academy of Fine Arts this evening—that the meeting be adjourned.

Mr. Mitchell explained that the passage of the motion just made would involve an adjournment until the third Wedesday of May, and as he desired to present to the Institute some important correspondence relative to the action of the Board of City Trusts in the matter of the award of the Scott Legacy Premium and Medal, he moved, as an amendment, that the meeting be adjourned to Wednesday, the 26th inst. The amendment was accepted by the original mover, and, as thus amended, the motion was carried.

WILLIAM H. WAHL, *Secretary.*

"ADAPTATION OF EULER'S FORMULA," ETC. (BURR).

ERRATUM.—In April issue, page 257, 9th line from top, for "cannot" read "can only."

JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXIII. JUNE, 1882. No. 6.

ON THE SEVERAL EFFICIENCIES OF THE STEAM ENGINE, AND ON THE CONDITIONS OF MAXIMUM ECONOMY.

By ROBERT H. THURSTON.

Presented to the American Society of Mechanical Engineers, Philadelphia Meeting, April, 1882.

SECTION II.—APPLICATIONS AND DEDUCTIONS.

11. Method of Construction of the Diagram of Efficiencies.

By the application of this method, as proposed by the writer, we may thus determine, from the results of experiment, a set of data and a graphical representation of those results which may serve as a standard for the class to which the engine examined belongs.

It is further evident that, the ratio of expansion at maximum efficiency being determined by experiment, and with precision by this graphical method, it becomes easy to ascertain with exactness the value of the ratio of expansion at maximum commercial economy.

The base line, VL, for maximum efficiency of engine being fixed, the position of the point V on that line is readily obtained, and thus the line VZ becomes known, and the ratio of expansion at maximum commercial economy is determined. Similarly, by extending the line VL until it becomes proportional to the sum of all costs, constant and

variable, the ratio of expansion giving maximum work per dollar expended with the given engine, may, if desired, be found.

The accompanying plate represents a series of real Curves of Efficiency, several of which are given by working engines. Such curves are here, for the first time, presented.

The straight line $A_1 A$, for the case in which $[n = (-1)]$ is the line of Constant Efficiency obtained in an assumed case of no gain and no variation of efficiency with increasing expansion from $r = o$ to $r = \infty$.

The curve marked G, and dotted, is the standard Curve of Efficiency for adiabatic expansion of steam containing initially ten per cent. water, $(n = 1{\cdot}125)$.

The line F is the Curve of Mean Pressure or of Efficiency for steam initially dry $(n = 1{\cdot}135)$.

The other curves are all obtained by reference to experiments on various classes of engines. B is the Curve of Efficiency for the common marine, unjacketed, single cylinder, condensing engine; C is the Curve of Efficiency for the same engine using superheated steam; D is that of a "compound" jacketed, condensing, marine engine; E applies almost exactly to both non-condensing engines and compound engines of the best classes, and the curve F is practically correct for the last named class of engines when the steam is kept thoroughly dry by effective superheating and reheating in a receiver.

Curve B is thus obtained:

Collating Isherwood's with other experiments made for the United States Navy Department, which are almost the only valuable experiments for our present purpose ever made on this class of engine as used on our river steamboats and in the Naval Service,* we find the following relative measures of steam consumption at various ratios of expansion, and of work done by it:

Cut-off $\frac{1}{r}$ (real), . .	·1	·3	·5	·7	·9	1·00
" $\frac{1}{r^1}$ (apparent), .	·05	·25	·47	·68	·89	1·00
Relative weights of steam, .	·16	·41	·60	·76	·92	1·00
" "total work" done,	·21	·56	·82	·97	1·00	1·00

* "Researches in Engineering," Vol. ii, Table, p. xxxiv.

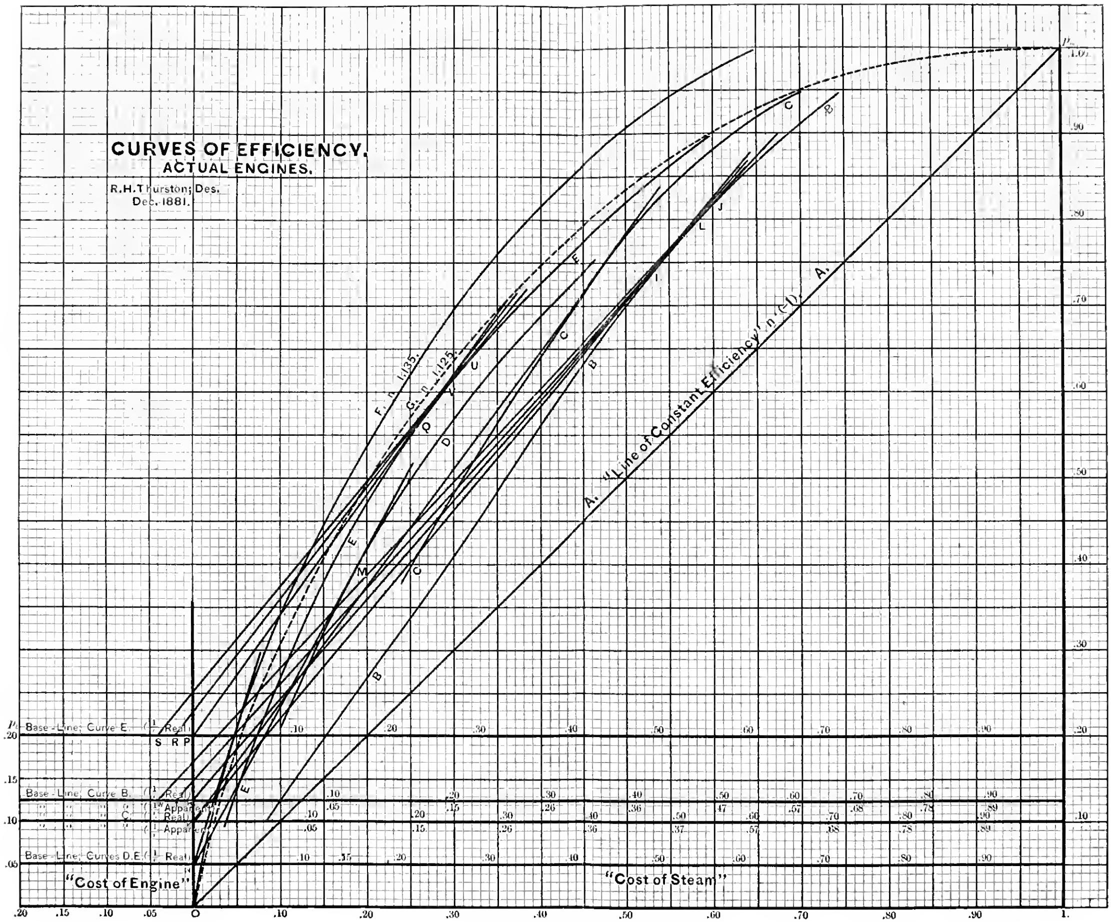

CURVES OF EFFICIENCY.
ACTUAL ENGINES.
R.H.Thurston; Des.
Dec. 1881.
"Line of Constant Efficiency" n (=1).
"Cost of Engine"
"Cost of Steam"
Base-Line; Curve E.
Base-Line; Curve B.
Base-Line; Curves D.E.
F. n 1:135.
G. n 1:125.

Plate I.

The base line, B, for this case, in which $\frac{p_b}{p_1} = \frac{1}{8}$, is drawn on the plate, and on this line are a set of values of $\frac{1}{r}$ corresponding to the relative weights of steam as laid down on the bottom scale, ·10 above ·16, ·30 above ·41, etc., etc., and the ordinates erected at these points are made proportional to the total work done at those ratios of expansion, and, thus carefully laying down these points, the line B_1 B is constructed as the Curve of Efficiency for the engine, of which those of the United States Steamers *Eutaw*, *Michigan*, and all "American River Steamboat Engines" are representatives.

In a similar manner, by collating the data obtained by the trial of the *Georgiana's* engine, using superheated steam, with the experiments of Hirn showing a reduction of exhaust waste by superheating, we obtain the Curve of Efficiency C_1 C and the Base Scale accompanying it.

A set of experiments on the *Bache* gives the line D_1 D, and the curve E_1 E is found, by trial, to meet cases of good work with non-condensing engines, unjacketed, but worked at high piston speed, and of some of the very best results obtained with compound engines of the most successful types.

Curve F seems to meet those cases in which superheating has been so efficient as nearly to prevent all condensation, and the line corresponds closely with the adiabatic for steam, dry initially, and only condensing so much as is due to the performance of work.

The location of these lines, as well as their form, is evidently variable with every change affecting efficiency.

The writer has been unable to find sufficiently complete series of experiments reported to construct these last curves as exactly and satisfactorily as the first, and has been compelled to work from scattered and comparatively incomplete data. The results, so far as comparable with practice, seem to indicate sufficient accuracy to have been obtained for such illustration as is here necessary; but extended experiments on the more modern engines—like those experiments for which we are indebted to Isherwood, on earlier forms—are much needed. Even curve B is not as far removed as it should be from the adiabatic curve since it is constructed on the assumption that re-evaporation could be neglected in the case studied, an inexact assumption, but one made necessary by the absence of data relating to

condensation at the point of cut-off.* The writer would be inclined to increase the proportion of loss taken from the record by at least an additional 10 per cent., making the total, probably, equal to

$$h_c = 0 \cdot 2 \sqrt{r} \text{ nearly.}$$

To obtain an exact solution of these problems the quantity of steam present in the cylinder *at the point of cut-off* must be precisely measured and compared with the quantity sent to the engine from the boiler. This absolutely essential comparison has been very rarely made by engineers conducting trials of steam engines.

12. Method of Application of the Method and Use of the Diagram.

Comparing curves F and G, representing the case of steam expanding in a non-conducting cylinder, *i. e.*, adiabatically, with the other curves, obtained for expansion in real engines, it is seen, at a glance, that the more perfectly exhaust-waste by cylinder condensation is guarded against, the more closely does the actual engine approach to the perfect engine in its utilization of steam, and the less effective the provision against such loss the more widely does the Curve of Efficiency depart both in location and form from the ideal curve, finally approximating to the straight line of Constant Efficiency $A_1 A$. While the best engines approach comparatively near the curve of maximum possible efficiency, the great majority of condensing engines in use are of the class represented by that giving Curve B; which latter is, however, by no means a case of remarkably low efficiency. In many cases the curve will be found to fall within the line B.

Selecting one of these curves, as B, or C, we may solve either or all of the problems already defined by merely applying a straight-edge to the diagram. For B we have $p = 40$; $p_b = 5$; $\frac{p_b}{p_1} = \frac{1}{8} = 0 \cdot 125$. To determine the Ratio of Expansion at Maximum Efficiency, draw the base-line at the altitude $0 \cdot 125$ and from its junction with the ordi-

* In fact, the only nearly complete sets of essential data given on any engines are those published in reports of U. S. Naval Engineers. Investigators have not yet learned the importance of ascertaining, in every engine trial, the weight of water passing through the engine and of comparing it with the weight of steam present *at each point* of the stroke as measured by the indicator. Where experiments, otherwise valuable, have been made it has rarely occurred that any one set of conditions has been preserved constant, while observing other variables, so as to secure any useful data for investigations like the present. Professor Cotterill's treatment should be applied in every case to secure a full and satisfactorily valuable set of data.

nate at the zero point, draw the line HI tangent to the curve; it touches the curve at I and the corresponding ratio of expansion on the base line beneath is a trifle less than $\frac{1}{r} = 0{\cdot}4$; $r = 2{\cdot}5$ nearly—a result confirmed by reference to the original data.

Next ascertain the hourly or annual cost of supplying the engine with steam worked without expansion, including all items of expense variable with the quantity of steam used, and determine the *variable* part of all running expenses in the engine room, including interest, insurance, rent, cost of oil and so much of the wages of the attendants as is properly taken as variable with the size of engine. Suppose, as in a case taken by the writer, that the latter is found to be two per cent. of the former, $M = {\cdot}02$.

From the point T, at the ordinate ·02, on the left of the H, draw the tangent to the curve as TL on the curve B; its point of tangency identifies the best ratio of expansion for commercial efficiency.

Similarly compare the "cost of full steam" with the sum of all other running expenses chargeable to the plant; if the ratio is $N = {\cdot}04$, draw the tangent line WL from the ordinate ·04 and thus find that ratio of expansion which will give most work for the money expended on a plant already installed. The lines PQ, RV and SU thus determine these three ratios for the curve F, of a well-constructed non-condensing engine, using perfectly dry steam and with a ratio $\frac{p_b}{p_1} = 0{\cdot}20$. The line NM determines the ratio of expansion at maximum efficiency for the case D, a compound engine doing good work with $\frac{p_b}{p_1} = {\cdot}05$.

13. *Estimation of Expenses.*

The following example illustrates, in detail, the calculation of M and N:

Rated power of given engine and boiler, . .	500 HP
Working time, per annum, . . .	3,000 hrs.

(A.) Cost of engine (variable with size of engine).

Cost of engine, ...		$10,000
Annual interest at 6 per cent., . .	$600 00	
" cost of repairs and depreciation, 4 per cent.,	400 00	
" " materials used, . .	50 00	
Total annual cost, . .	$1,050 00	

(B.) Costs of boiler (variable with demanded boiler-power).

Cost of boiler; actual, $12,000, for "full steam,"	$24,000	
Interest on cost, using steam without expansion, at 6 per cent.,		1,440
Repairs and depreciation at 15 per cent.,		3,600
Minor expenses per annum,		200
Total annual maximum cost,		$5,240

(C.) Fuel Account (variable with size of boiler).

Coal, per year at the rated power,		2,000 T
" " " with no expansion,		4,000 T
Cost of fuel at "full steam," at $5 per T,	$20,000	
" " transportation and storage at 50c.,	2,000	
Total maximum per year,	$22,000 00	

(D.) Attendance (wholly or partly constant or variable).

(*a*) "Engine-driver's" (engineer's) pay, per year,	$1,000 00
(*b*) "Firemen's" (stokers') pay, per year ("full steam"),	1,200 00
	$2,200 00

(E.) Incidentals (constant as a rule).

Rent, taxes, insurance, etc., per annum, . . $1,000

Studying the statement of costs, the mechanical engineer decides in each case, and for each problem presented how the items should be grouped. For the case of a stationary steam engine such as is here presented, he would find:

$$M = \frac{(A)}{(B) + (C)} = 0{\cdot}035, \text{ nearly}$$

if the costs (D_a), (D_b) are not variable within the probable range of variation; or

$$M = \frac{(A)}{(B) + (C) + (D_b)} = 0{\cdot}03, \text{ nearly}$$

if the cost of fire room labor is variable with quantity of steam demanded. Then

$$N = \frac{(A) + (D) + (E)}{(B) + (C)} = 0.15 \text{ nearly}$$

for the first case, and

$$N = \frac{(A) + (D_a) + (E)}{(B) + (C) + (D_b)} = 0{\cdot}10, \text{ nearly}$$

for the second case. In marine steam engineering, storage becomes an important matter, in items (A) and (D); and (B) as well as very important in (C) and (E), since every cubic foot occupied by machinery, fuel or attendants displaces a cubic foot of paying loading. With very large powers, the items (D) both become to a certain extent variable, the one (D_a), with magnitude of the whole plant, the other (D_b) with quantity of fuel burned. Correctness in making up the bill of costs will be found to be absolutely essential.

14. Statement of Results.

Laying out these curves on a conveniently large scale and proceeding as just indicated, the writer obtained the results exhibited in Table I, here given. Cases I to VI, inclusive are obtained from Curve E; VII to XII from Curve B; XIII to XVIII from E, and XIX to XXIV from the best Curve of Efficiency, on the plate, Curve F.

The Ratio of Expansion at Maximum Efficiency of Fluid will be found in column r_e^{i}, that at Maximum Efficiency of Engine under r_e^{ii}, and the Best Ratio of Expansion for Commercial Efficiency, or for Maximum Efficiency of Capital is given under r_e^{iii}, M, N, are the ratios of cost. Comparing the first, and especially the second, set with the last, the enormous variation due to cylinder condensation is readily appreciated. Even the last case is far from the efficiency of the perfect engine.

The ratios of expansion for superheated steam in the unjacketed cylinder are obtainable from Curve C.

[P = Initial Pressures measured from perfect vacuum; P_3 = Back Pressure in cylinder; P_b = Same plus friction; M = Ratio of variable part of cost of engine to variable part of cost of steam, when $r = 1$.

r_e^{i}, r_e^{ii}, r_e^{iii} = Ratios of Expansion of Maximum Efficiency of Fluid, of Engine and of Capital invested to obtain a Given Amount of Power with best engines of each class.]

The values here presented for these several cases are not to be taken by the engineer as exact for other examples. They are given as representative cases, and the engineer designing new engines should, whenever possible, construct his own diagram and make his own solution of the problem before him.

TABLE I.

Ratios of Expansion at Maximum Efficiency of Fluid, of Engine and of Capital.

SINGLE CYLINDERS.

Absolute Initial Pressures.			Case No.	Class I. Non-condensing, High Speed.							Case No.	Class II. Condensing, Moderate Speed.						
P	P_m	Atmospheres.		P_3	P_b	M	$\frac{p_1}{p_b}$	r_e^{i}	r_e^{ii}	r_e^{iii}		P_3	P_b	M	$\frac{p_1}{p_b}$	r_e^{i}	r_e^{ii}	r_e^{iii}
40	2·8	$2\frac{2}{3}$	I	18	20	·02	2	2	2	2	VII	3	5	·04	8	$2\frac{1}{2}$	$2\frac{1}{4}$	2
60	4·2	4	II	18	20	·02	3	3	3	$2\frac{3}{4}$	VIII	3	5	·04	12	$3\frac{1}{2}$	$3\frac{1}{4}$	3
80	5·6	$5\frac{1}{3}$	III	18	20	·02	4	4	$3\frac{3}{4}$	$3\frac{1}{4}$	IX	3	5	·04	16	$4\frac{1}{4}$	4	$3\frac{1}{2}$
100	7·0	$6\frac{2}{3}$	IV	18	20	·02	5	5	$4\frac{1}{2}$	$3\frac{1}{2}$	X	3	5	·04	20	$4\frac{3}{4}$	$4\frac{1}{2}$	4
120	8·4	8	V	18	20	·02	6	6	$5\frac{1}{2}$	4	XI	3	5	·04	24	$5\frac{1}{2}$	5	$4\frac{1}{2}$
150	10·5	10	VI	18	20	·02	$7\frac{1}{2}$	7	6	$4\frac{1}{2}$	XII	3	5	·04	30	6	$5\frac{1}{4}$	5

COMPOUND, CONDENSING, JACKETED.

Absolute Initial Pressures.			Case No.	Class III. Saturated Steam.							Case No.	Class IV. Superheated Steam.						
P	P_m	Atmospheres.		P_3	P_o	M	$\frac{p_1}{p_b}$	r_e^{i}	r_e^{ii}	r_e^{iii}		P_3	P_b	M	$\frac{p_1}{p_b}$	r_e^{i}	r_e^{ii}	r_e^{iii}
40	2·8	$2\frac{2}{3}$	XIII	3	$5\frac{1}{2}$	·04	7	6	5	3	XIX	$2\frac{1}{2}$	5	·05	8	8	6	5
60	4·2	4	XIV	3	$5\frac{1}{2}$	·04	11	8	7	$4\frac{1}{2}$	XX	$2\frac{1}{2}$	5	·05	12	11	8	6
80	5·6	$5\frac{1}{3}$	XV	3	$5\frac{1}{2}$	·04	14	9	8	6	XXI	3	$5\frac{1}{2}$	·05	13	14	10	7
100	7·0	$6\frac{2}{3}$	XVI	3	6	·04	17	10	9	7	XXII	3	$5\frac{1}{2}$	·05	18	16	12	8
120	8·4	8	XVII	3	6	·04	20	11	10	8	XXIII	3	$5\frac{1}{2}$	·05	22	20	15	9
150	10·5	10	XVIII	3	6	·04	25	13	10	9	XXIV	3	6	·05	27	25	17	10

Further investigation will, undoubtedly, sooner or later, establish the Curves of Efficiency for those classes of engine and for those special cases for which the engineer can to-day only obtain them approximately. Meantime, the plate exhibits a range of variation of curve which extends completely across the field of every-day practice, and an experienced engineer can readily trust his judgment in the interpolation of the curve of efficiency for any special case arising in his own practice. For example: Cases of best practice in which the engine is worked at higher speed, and with a warmer condenser, and having less friction, will give a curve for the class from which B was obtained, which will fall between B and C.

The values given of $\frac{p_1}{p_b}$ are interesting in comparison with the values of r_e, as exhibiting this enormous difference between the best ratio of expansion in actual work and the ratio giving maximum efficiency in the ideal case, and also as strikingly presenting to the mind how far we are still, in actual practice, from even an approximation to the ideal conditions exhibited in the perfect engine.

TABLE II.

Ratios of Expansion giving Maximum Work at Minimum Cost for a Given Plant of Known Proportions.

	Class I.						Class II.					
Cases	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
N	·04	·04	·04	·04	·04	·04	·10	·10	·10	·10	·10	·10
r_e^{iv}	$1\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{1}{2}$	4	$1\frac{3}{4}$	$2\frac{1}{2}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	4

	Class III.						Class IV.					
Cases	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	XXII	XXIII	XXIV
N	·10	·10	·10	·10	·10	·10	·12	·12	·12	·12	·12	·12
r_e^{iv}	$2\frac{1}{2}$	$3\frac{1}{2}$	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{3}{4}$	4	$4\frac{1}{2}$	$4\frac{3}{4}$	5	5	$5\frac{1}{4}$

Table II gives values, similarly obtained for the cases taken, of that ratio of expansion which gives a maximum quantity of work for a dollar with a fixed proportion of plant. These values are seen to be very much smaller than the ratios for maximum commercial efficiency, and, although they may give more work for a dollar than the

higher ratios just determined, they do not give maximum efficiency of capital. For:

Assume the engine working at this nearly adjusted ratio for the now given power, still more work will be given for the dollar if the value of r be increased by replacing the given engine by a larger one, in many cases, or in any case by speeding up the engine or otherwise doing the larger amount of work with the higher ratio of expansion. The writer has sometimes accomplished this latter result by both speeding up the engine and carrying higher steam,* with an automatic adjustment of expansion. The real limit to this increase of work done by the given engine is determined by quite other considerations than those above noted. It is determined by the money value of the power obtained, and this increase of power finds a limit, as has been seen, only when either the limit of safety in working engine or boiler is reached, or when the money made by the use of additional power is insufficient to pay a fair profit on the additional expense incurred, which latter limit may be obtained at a value of r^{iv} either equal to or less than r_e.

15. Relation of Costs and Profits.

Table III exhibits the effect of variation of actual value of the power in determining the maximum amount profitably obtainable from any engine.

For example: Suppose the cost of a horse-power to be, as is frequently the case, about equal to the cost of fuel (in the furnace) producing that power without expansion; then calling this value P_m and this cost P_e, the base line of the diagram will be extended until it measures $\left(\frac{P_m}{P_e} = 1 = X^1\right)$ twice the length of OX, and the angle made by the line from its extremity to A, Fig. 2, makes an angle $\theta = 45°$ with OX. On the large-scale drawing, set the triangle against the edge of the T-square, and adjust it to the line here given; find by shifting it along the blade that point on the selected curve of efficiency at which a parallel tangent can be drawn, and then the ratio of expansion, r^v, answering to this case, is found.

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* A favorite occupation of the writer, when engaged in this branch of professional work, was that of designing new and larger steam cylinders for old engines, to meet this case.

If an engine, IV of Class I, is selected, it is found to be $r^v_\cdot = 2\frac{1}{2}$; if No. VII of Class II, $r^v = 2$, etc., etc., as in Table III.

It is particularly interesting and instructive to observe how the importance of cylinder condensation, in its influence on the best ratio of expansion, diminishes with decreasing expansion, and that, finally, the most economical and the least efficient give nearly identical figures when the point of cut-off approaches half stroke.

TABLE III.

Effect of Variation of Ratio to Market Value to Cost of Power. Maximum Limiting Values of r^v.

				N^1	0·40	0·50	0·60	0·70	0·80	1·00
Class		No.		IV	......	......	......	......	3	$2\frac{1}{2}$
"	II	"		VII	......	......	......	......	......	2
"	II	"		X	......	......	......	......	......	2
"	III	"		XV	......	7	5	4	3	$2\frac{1}{2}$
"	III	"		XVII	......	7	5	4	3	$2\frac{1}{2}$
"	IV	"		XXI	9	7	6	4	3	$2\frac{1}{2}$
"	IV	"		XXIV	10	7	6	4	3	$2\frac{1}{2}$
θ					22°	27°	31°	35°	39°	45°

Taking the cost of fuel, *in the furnace*, for the engine working without expansion, at \$50 per annum per horse-power, the above table gives the ratio of expansion below which a loss will accrue when the cash value of the horse-power is 20, 25, 30, 35, 40 and 50 dollars; at these ratios of expansion, all that is received for power above these sums is profit.

For other costs, the prices obtained must be correspondingly varied to secure a profit.

16. Profits at any Fixed Expansion.

Other problems, the converse of the last, may be solved by this construction: "What is the maximum price which can be paid for power without loss at any *given best ratio of expansion?*" "What profit is obtainable at lower costs?" "What total cost makes any given ratio the most economical ratio of expansion?"

To solve these problems, draw an ordinate to the line of mean pressures, or the curve of efficiency, at the assumed ratio of expan-

sion; the abscissa measures the cost in terms of full steam of the power measured by the ordinate, above which loss will accrue, when M = 0. The difference between the total cost and the price measures the profit obtainable if the power is sold at the higher of the two figures.

Table IV, exhibits the variation of the relative maximum allowable cost of power, with variation of the ratio of expansion, actual cost of expenses, variable with fuel without expansion, being taken as unity.

TABLE IV.

Maximum Limit of Relative Allowable Cost. Most Economical Ratio of Expansion assumed as r. Cost of Full Steam = Unity.

M or N = 0·1.

			r	1	2	3	4	5	6	8	10
Class	I	No.	IV	1·1	·80	·75	·75	·85	·85	.....	.....
"	II	"	VII	1·1	·80	·85	1.1	.....	.....	.....	.....
"	II	"	X	1·1	·75	·80	·95	.....	.....	.....	.....
"	III	"	XV	1·1	·75	·70	·70	·75	·80	·90	1·1
"	III	"	XVII	1·1	·75	·70	·70	·70	·70	·75	·90
"	IV	"	XXI	1·1	·75	·70	·90	·65	·70	·75	·90
"	IV	"	XXIV	1·1	·75	·70	·65	·65	·55	·55	·65

17. *Cost of Engine as Affecting the Best Ratio of Expansion.*

The effect of variation in cost of engine now becomes of interest, and indeed a matter of real importance to the designer. Studying cases arising in practice, he will probably find the value of M or N to fall between ·02 and ·15, as in those selected above, but it will probably rarely, if ever, exceed 0·20.

The curve being established correctly for any given engine, it becomes the easiest possible matter to determine the effect of variation of this ratio. Table IV gives such results as seem most instructive, from the cases here studied.

TABLE IV.

Effect of Variation of "Engine-cost Ratio." Best Values of r_e^{iii} *or* r_e^{iv}.

			M or *N*	·02	·04	·06	·08	·10	·15	·20
Class	I	Example	IV	$3\frac{1}{2}$	$3\frac{1}{4}$	3	$2\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{1}{4}$
"	II	"	VII	...	2	2	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{2}{3}$	$1\frac{1}{2}$
"	II	"	X	...	4	$3\frac{3}{4}$	$3\frac{1}{2}$	$3\frac{1}{4}$	$2\frac{3}{4}$	$2\frac{1}{2}$
"	III	"	XV	...	6	5	$4\frac{1}{4}$	4	$3\frac{1}{2}$	3
"	III	"	XVII	...	8	6	$4\frac{3}{4}$	$4\frac{1}{2}$	$3\frac{3}{4}$	$3\frac{1}{4}$
"	IV	"	XXI	...	$6\frac{1}{2}$	6	$5\frac{1}{2}$	$4\frac{3}{4}$	$3\frac{3}{4}$	$3\frac{1}{4}$
"	IV	"	XXIV	...	9	7	6	5	4	$3\frac{1}{2}$

These differences in the value of the ratio of expansion at maximum commercial efficiency are least where the exhaust wastes are greatest, and as their absolute values become smaller. Cases IV, X, XVII and XXIV have the same initial steam pressure and are seen to approximate toward the same value of r_e as the value of M or N becomes greater, becoming, for the first two, and for the last two, nearly equal to the maximum value here taken.

It is obvious that the value r_e becomes a good gauge of the economical value of the engine, and that the greater these values and the nearer r_e^{ii}, r_e^{iii}, r_e^{iv} approach each other, in any given engine, the better the design.

It is now seen that we have here a method of determining the effect of variations of single variable quantites, while retaining all others constant—a method very greatly needed, but hitherto unknown.

The case just taken is an illustration of its application. The following is another instance of no less importance.

18. Back Pressure as Modifying Economy.

The Effect of Variation in Back Pressure may be studied, by means of this method of investigation, with the same facility.

Table V exhibits this effect for a wide range of cases.

TABLE V.

Effect of Variation of Initial Pressure and of Back Pressure.
Best Values of r_e^i.

			$\frac{p_b}{p_1}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{5}$	$\frac{1}{6}$	$\frac{1}{8}$	$\frac{1}{10}$	$\frac{1}{15}$	$\frac{1}{20}$
Class	I	No.	IV	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{1}{2}$	...	...	...	...
"	II	"	VII	$1\frac{1}{2}$	$1\frac{2}{3}$	$1\frac{2}{3}$	$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{1}{2}$	...	...
"	II	"	X	...	...	...	$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{1}{2}$	3	4
"	III	"	XVI	...	...	...	$4\frac{1}{2}$	6	7	9	11
"	IV	"	XXII	...	...	...	6	6	8	12	15

These differences in value of r_e are obtained on the assumption that cylinder condensation and all other conditions remain unchanged while variation occurs in the back pressure. In all actual cases, the differences would be reduced by the fact that increased condenser-pressure and the reduction of chilling effect which comes with increase of back pressure so check exhaust waste that the ratio for maximum efficiency becomes somewhat increased and these differences of ratio

are thus lessened. The gain from this and other causes becomes sufficient at high pressures to justify the use of the simpler and less expensive non-condensing engine; it will be best appreciated after comparison of Class I with Class II.

19. Illustrations of the Value of Results.

In illustration of the use of this method and of the application of the results, we may observe as in Table I values of the ratio of expansion for maximum efficiency for any standard type of engine. Thus: Case III is that of an ordinary, standard, non-condensing, drop cut-off engine, steam 65 pounds ($5\frac{1}{3}$ atmospheres) by gauge, and the cut-off occurs, properly, at a little inside $\frac{1}{4}$ stroke; Case V is the same with steam at 105 by gauge (8 atmospheres) and its valve should close a little inside $\frac{1}{5}$ stroke.

For maximum *commercial* efficiency those engines should "cut off" at about $\frac{1}{3}$ and $\frac{1}{4}$ respectively.

In the second class, Case VII is that of the old naval or modern very low-pressure river-boat engine carrying 25 pounds of steam by gauge ($2\frac{2}{3}$ atmospheres). The valve should drop so as to completely shut off steam at about half stroke to give minimum expenditure for coal and a little later to give minimum cost on total account,* a result already reached by the builders of such engines.

Case VIII is that of some of our Hudson river steamboats (steam 45 by gauge) and these two ratios are found to be a little greater and a little less than 3.

The irregularity of wheel which a short cut-off produces, however, makes it inadvisable to expand as much as this, even.

Case IX is often seen in mill engines; its valve closes at $\frac{1}{4}$ and $\frac{1}{3}$ for the cases taken. Above this pressure, a comparison of Class I with Class II shows that in the cases taken the non-condensing engine is about as economical as the other—a conclusion justified by Isherwood's comparison of Corliss engines†—but comparing values of r_e^{iii} it is seen that the condenser may probably be exchanged for the heater with Classes III and IV only at some very high pressure not yet

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* Engines of this class by good builders, having the "Stevens Valve-gear," close the valve at 6 feet on a 10 feet stroke, which, allowing for a little throttling, gives exactly this figure. Those fitted with the "Sickles Cut-off," drop the valve as near half-stroke as possible; they cannot "follow" further.

† Journal Franklin Institute, Sept., 1881.

attained with jacketed engines of good design, while the ten per cent. gain obtained at the boiler by the higher temperature of feed given by the heater of the non-condensing engine, together with the differences in size of cylinder, brings down the pressure at which total efficiency becomes a minimum to some lower figure which may be determined, by the method here given, for any given case.

Cases XV and XVI are commonly illustrated on transatlantic steamers and by the best compound pumping engines. The cut-off takes effect at $\frac{1}{8}$ or $\frac{1}{9}$ for maximum efficiency of engine and fuel, and at $\frac{1}{6}$ or $\frac{1}{7}$ for most economical expenditure of money,* figures already settled upon by the most successful builders.

Cases XII and XIII represent the most advanced practice in the use of high steam pressure, superheated steam and reheating at the intermediate receiver, as is done in the pumping engines of Cowper, Corliss and Leavitt. The best ratios of expansion are 12 and 15, if measured by duty attained and fuel saved, simply, and two-thirds those values give maximum efficiency of capital. Case XXIV represents most nearly the case of Corliss' best pumping engine, which lies between XXIII and XXIV, its best ratio of expansion lies between 9 and 10, if the Curve of Efficiency here taken for Class IV suits that case. If nine is the *real* ratio, the *apparent* cut-off will be nearly at one-tenth, while for maximum efficiency of engine and maximum "duty" the valve should drop at about one-sixteenth stroke.

It should be carefully kept in mind that the measure of cost, in all problems relating to expense, as here treated, is the total cost per annum, without expansion, of all items of Class 3, *i. e.*, variable with variation of steam supply.

The problem illustrated by the cases taken up in Table II would seem to be of rare occurrence. In fact, the writer has been able to imagine but two such cases:

(1). Where the proprietor of an engine can rent power from an engine already set up with boiler power sufficient to supply an ample amount of steam, he will obtain the best return from his invested capital by delivering so much power at remunerative prices as will give the values r_e^{iv}, found in Table II. Cases IV, V and VI are such as are most usual, the best point of cut-off averaging about $\frac{1}{3}$ stroke.

Had the power to be demanded been known, the proprietor would

* *Vide* "Clark's Manual for Mechanical Engineers," pp. 888, 890.

have done better to have put in a larger or a faster running engine with a higher ratio of expansion, and would usually find it economical to alter the engine here assumed to be used—in the manner already described—if possible, so as to deliver the maximum power, working at the shorter cut-off.

(2). The second is that of a naval engine intended to work with maximum efficiency at low power or long runs and only requiring high power for short periods of time. It has sometimes been customary to design such engines to work with high ratios of expansion while cruising, and to develop full power with less expansion when in action, supplying a fan blast for the latter occasion. For such cases the best ratio at low power would be r_e^{ii}, and it might be well to make the expansion variable through as wide a range as from r_e^{ii} to r_e^{iv}, taken with extreme values of M and N. As already stated, in all ordinary work, the Ratio of Expansion at Maximum Commercial Efficiency is the ratio of expansion to be adopted for any engine.

The values here given for M and N are based on cost of fuel taken at \$5.00 per ton. The value of the ratios of expansion at maximum efficiency will be less at lower prices and greater at higher costs, the expenses of maintenance of plant being constant, since the values of Cost of Steam will be directly and of M inversely as the price of fuel. With coal at ten dollars per ton, M will be practically one-half the figures given above and the least ratio of expansion correspondingly increased as per table V.

Table III may be consulted by the owner of steam power for cases which, as is usual, fall within the given limits. For exceptional cases he, or his consulting engineer, can, when data are obtainable, always make his own curve of efficiency and obtain a practically exact solution of the case presented.

20. Variation of Cylinder Condensation with Expansion.

One other among the numerous problems capable of solution by this most prolific of methods promises, in the opinion of the writer, to prove, in the future, both interesting and important:

"*Given:* the method of variation of efficiency with varying ratios of expansion or proportions of steam used, to determine the method of cylinder condensation with varying values of $\frac{1}{r}$."

To solve this problem, construct the Curve of Efficiency, as A, D,

E, O, Fig. 2, and draw the curves of adiabatic mean pressures for various values of x, as in dotted lines in that figure.

The points of intersection of these curves with the curve of efficiency identify the ratios of expansion at which the total condensation amounts to the proportion due to the adiabatic line so cut.

In all problems of maxima or minima solved by the construction here given it will be observed that the item of quantity of expenditure made the independent variable is that dependent upon the quantity of steam or of fuel demanded by the engine.

21. Problems solved by the Inspection of the Diagrams.

An important class of problems of simple character may be solved with still greater ease and rapidity by the use of the Curve of Efficiency for the class of engine studied in any case, *e. g.:*

(1). To determine the gain or decrease of power obtainable by change of ratio of expansion or point of cut-off, measure the ordinates of the curve at the present and at the proposed ratio of expansion; their relative magnitude will be a measure of the relative power of the engine at the two points of cut-off if using the quantity of steam measured by the abscissas.

(2). To determine the quantity of fuel or of steam, per hour per horse-power, to be gained or lost by change of the ratio of expansion, compare the value of ratios of abscissa to ordinate at the existing and proposed points of cut-off; their relation will be that of cost of power in steam or in fuel.

(3). To determine the absolute amount of fuel or of steam per horse-power and per hour consumed, at any assumed rates of expansion, first calculate the consumption for the given engine as a thermodynamic problem simply, and multiply by the ratio, $\frac{y}{p_m}$, of the mean pressure in the perfect engine at the given expansion to that shown by the true Curve of Efficiency for the engine studied. Or, calculate the consumption for the engine working without expansion and without waste, and multiply by the ratio, $\frac{p_1}{p_m y}$, obtaining y and p_m from the diagram *N*, the given cut-off, and remembering that p_1 measures the mean pressure at full stroke of the given steam used *dry*.

It is evident that when costs of engine can be referred, as here taken, to the same unit of volume, the solution of the problem of

maximum commercial efficiency is independent of size of engine and of the absolute measure of power demanded and hence applies to all engines of the same pattern.

22. *Conclusion.*

In view of what has preceded, it becomes obvious that the engineer purposing to write a specification for steam machinery on which bids are to be made with guaranty of performance should *first* determine the probable *Curve of Efficiency* for the Kind of Engine called for and solve the above problems relating to its economy. He should then prescribe the ratio of expansion at which maximum duty is to be obtained, as well as fix the duty expected in regular work, at which ratio the work done will be less than the regular working power of the machine. He must also indicate at what degree of expansion the engine will be required to do its ordinary work at maximum *commercial* efficiency, and should state what minimum commercial economy at that rate of work will be accepted. Finally, it should be prescribed that the engine should be capable, if its work should be increased, of attaining at least its maximum "efficiency of plant" with safety, and with a specified efficiency which should be reasonably high.

Thus fixing the ratio of expansion on the duty-trial, the builder is able to give an intelligently estimated guaranty of performance at highest efficiency; settling the ratio of expansion for maximum commercial efficiency in regular work fixes the proper size of engine, and the last specification secures ample strength of parts. Costs must be carefully estimated for the given locality. In what has preceded, the calculations have been based on cost of fuel estimated at $5.00 per ton, and labor at $2·00 to $3.00 per day, and interest at 6 per cent.

In laying out the curve of efficiency from experimental data it will be found necessary to be especially careful to establish the usually irregular scale of $\frac{1}{r^1}$, the points of cut-off, in their correct relation to the regular scale of steam expenditure and "cost of steam."

By the use of this, or some more exact method, the art of proportioning the steam engine can be elevated to the rank of a branch of the Science of Engineering, and that part of that science which has hitherto been in a most unsatisfactory, as viewed from the standpoint of the engineer engaged in its application, may be found to take a comparatively complete and useful form.

This subject is here presented only provisionally. The effects of varying compression and of conditions relating to regulation, as well as many other minor matters, remain to be studied. In a first survey of so broad a field, and especially where the needed data are so difficult to obtain and so uncertain as to accuracy, the writer cannot hope to have completely and exactly established all the results sought by him, and a revision of this work in the light of further investigation will probably ultimately lead to more correct and more valuable determinations.

It is even to be hoped, if not expected, that an exact theory of steam engine economy may, at some early date, be produced, and that thus the engineer may be enabled to obtain solutions of all such problems with all the precision that can ever be desired.

Hoboken, N. J., January, 1882.

NINETY MILES IN SIXTY MINUTES.

By W. Barnet Le Van.

Read before the Franklin Institute, at the Stated Meeting, December 15, 1880.

(Concluded from page 173.)

Fast Locomotives.

In my plan of reaching a speed of *ninety miles an hour*, I propose that the locomotives shall be of a minimum weight with a maximum power. To produce this I must have, as I have before stated, a high piston speed and a corresponding high steam pressure, inasmuch as the reduction of the weight involves a corresponding reduction of the adhesion. This latter must be made up for by a higher boiler pressure. I also propose to use the steam more expansively, by having separate cut-off valves working on the backs of the main valves, which are connected with the ordinary link so that the engines may be readily and quickly reversed and run in either direction.

It is well known to locomotive engineers that the distribution of steam by the link motion is neither economical nor satisfactory, and for fast-running locomotives there are substantial demands for an improved condition.

If a locomotive, fitted with a link motion, is raised from the rails,

and its wheels revolved in the air, it will be found that with the same opening of the throttle the wheels will revolve faster when the link is nearly in mid gear than when in full gear. The compression of steam, with an early cut-off, arrests the momentum of the reciprocating and unbalanced revolving parts, and increases the rapidity of their motion. With an independent cut-off valve the compression of the exhaust steam can be made constant at all points of cut-off, there being no variation of lead, and the link being used simply as a ready means of reverse.

Independent cut-off valves are not new in locomotives, having been used many years back with great success, and I do not know any valid reason why they should have been dispensed with. It is well known that flat-wearing surfaces, having a constant travel to and with each other, and balanced, have a tendency to increase their tightness by continued use.

In 1841 Horatio Allen, of New York, patented a cut-off valve formed of two blocks moving on the back of the main valve, and capable of being separated or brought together by a right- and left-hand screw, so as to vary the point of cut-off. This arrangement, which is often known as the Meyers valve, was introduced on a number of locomotives built in Austria, prior to 1849, Meyers having adopted this feature as well as some others from American designs.

In March, 1850, Mr. Ethan Rogers, of the Cayahoga Works, Cleveland, Ohio, completed a locomotive in which the cut-off valves were worked with an adjustable throw from curved rocker arms, the arrangement being known as the sword cut-off; and within a few weeks of the same time, Mr. Horace Gray, of Boston, introduced a similar arrangement upon one of the engines running on the Fitchburg Railroad. This construction, which was adopted by numerous builders, was found to be very efficient, and though temporarily laid aside with the view of simplifying mechanism will, I think, be found to be desirable, and will be again adopted for high-speed locomotives.

The substitution of a separate cut-off valve will give fifty per cent. more power with the present sized boiler used, independently of reducing the consumption of coal and water.

I also propose to return to the fire-box for consumption of the particles of unconsumed coal which are clipped off by the force of the exhaust, and carried through the tubes, instead of, as is now the case,

throwing them out of the stack over the roads and into the car windows.

I also propose to so construct the permanent way that stations shall be located on summits, that the force of gravity of the train may assist the locomotive in starting and stopping, it being important in operating a high speed railroad to lose as little time at the stations as possible, either in stopping or starting; and it is also important to keep up a rapid speed to a point as near the station as possible, and in starting to get the train under full speed in the least possible space of time. The advantage of this plan will be the gain of the work (*vis viva*), or force stored in the moving train, the product of its weight and speed, which in the usual plan is annihilated by the tracks, and lost forever, thrown away as if it did not cost anything to create it. In addition to this loss there is, from the excessive use of the brakes, another serious loss in the rapid destruction of the rails and wheels and locomotives, the engines being often reversed, and the steam used to assist in destroying what it created; but by the gravity system a light locomotive will perform the same work at a less cost.

To provide, in a simple manner, against the entire loss in stopping at stations, and to insure that the stopping and starting shall be done in the most efficacious and expeditious manner, is my desire in proposing to bring the great power of gravity to assist both in stopping and starting, and to that end to place all stations on a summit especially provided for it, so that which is apparently lost in stopping is again recovered in starting. At any fixed speed this could easily be so arranged that the brakes would hardly be required.

Large Drivers.

I am aware that the larger the driving wheels are made the greater will be the elevation of the centre of gravity of the locomotive; but this can be no objection when the permanent way is built to suit the higher speed.

A large wheel has certain advantages as compared with those of small diameter. Every point, in the circumference of the tire, is presented to the rails, as much oftener, in a given distance, as the wheels are smaller. Hence the wear of tires, under a given load should be inversely as their diameters.

There is also another important factor to be considered at the high piston speed, 1500 feet per minute, namely, the supply of the steam,

and this is one of the reasons why I have fixed on *six feet* diameter of driving wheels.

To compensate for my high piston speed and the limited space of my boiler I propose to use a steam pressure of 200 pounds to the square inch; and a 15-inch diameter cylinder and a stroke of 21 inches and run 420 revolutions per minute, which will use but half the quantity of steam that would require a cylinder 17 inches diameter and 24 inches stroke, making 300 revolutions per minute, this latter being that of the standard-sized passenger locomotive on most of our leading roads, using steam of 125 pounds pressure to the square inch, with 66-inch diameter drivers.

Assuming 125 pounds as the steam pressure now used, with the above-mentioned locomotive, the horse-power developed when cutting off at one-half the stroke will be as follows:

$$\text{HP} = \frac{226 \times 1200 \times 35}{33000} \times 2 = 569 \text{ horse-power.}$$

And with a locomotive with 15-inch diameter of cylinder, 21 inches stroke, making 420 revolutions per minute, and a boiler pressure of 200 pounds per square inch and cutting off one-half the stroke, will be as follows:

$$\text{HP} = \frac{176{\cdot}7 \times 1500 \times 60}{33{,}000} \times 2 = 964 \text{ horse-power}$$

showing nearly double the horse-power of the former.

The tractive force of the $17'' + 24''$ locomotive, with 66-inch drivers, will be as follows:

$$T = \frac{17^2 \times 24 \times 35}{66} = 3678 \text{ pounds,}$$

and of the $15'' \times 21''$ cylinder, with 72-inch drivers, will be as follows:

$$T = \frac{15^2 \times 21 \times 60}{72} = 3937 \text{ pounds.}$$

Defects in our System of Railways.

The one great defect in all railways is, that they present such imperfect rolling and grinding surfaces that the resistance to traction increases in a rapid ratio to the speed. The resistance, apart from that of the atmosphere, should be the same at 90 miles an hour as at nine. Not that the power would be the same, for that is the product

of resistance into the velocity at which it is overcome, and it would thus, under the very best conditions require ten times as much power to move a train at ninety miles an hour as at nine, supposing the resistance or pull on the draw bar, between the locomotive and train, to remain all the while the same. With our present conditions of railroads it requires something like twenty or thirty times the power to move at the higher than at the lower speed, or in other words, from two to three times the average piston pressure, and six to eight times the piston speed. The rail and wheel should be fitted to work together like a "Waltham watch."

Like all the best examples of machinery, working by frictional contact, the rail and wheel should be in the identical conditions of the smoothest frictional gearing. There should be no blows here and lunges there, no sensible deflection of rail, and no grinding of wheel-flanges, nor running on unequal diameters where two wheels are fixed to, instead of being loose upon, the same rails.

The conditions of a perfect railroad are not impossible. True, the first cost will be much greater, but there has never been any attempt to effect the improvement, or to prove by experiment that the cost really would be conclusive against such a system of construction.

Mr. William H. Stewart says, in his opinion, "physical bonds—such as highways, canals, rivers and railroads—are vastly more powerful for holding civil communities together than any mere covenants, though written on parchment or engraved on iron."

The distance to be traversed by the present railroad lines, between Philadelphia and New York, is, by the Bound Brook line, 90·4 miles, as per following time schedule, June 21, 1880.

Miles.	Stations.		Time of leaving.
0·	9th and Green streets,	Phila. and Reading R. R.,	7·30 A. M.
4·3	Wayne Junction,		7·40 "
59·2	Bound Brook,		8·43 "
89·4	Jersey City,	New Jersey Central R. R.,	9·22 "
90·4	New York,		9·30 "

A change of locomotive is made at Bound Brook.

By the Pennsylvania Railroad, distance 89·4 miles, June 21, 1880.

Miles.	Stations.	Time of leaving.
0·	Thirty-second street, West Philadelphia,	7·35
4·2	Germantown Junction,	7·43
88·4	Jersey City,	9·29
89.4	New York, Courtlandt street,	9·35

The elevated extension to Fifteenth and Market streets will add an additional mile, making the distance by both exactly the same.

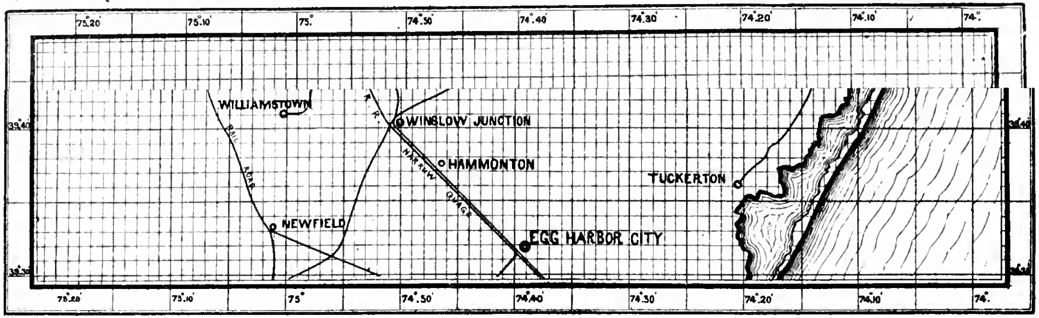
It is not to be presumed that the two largest cities on this continent, only 81 miles (80·94 exactly) apart from City Hall to City Hall in a straight line, and over a comparatively level country, will be satisfied until the time between them is reduced to one hour.

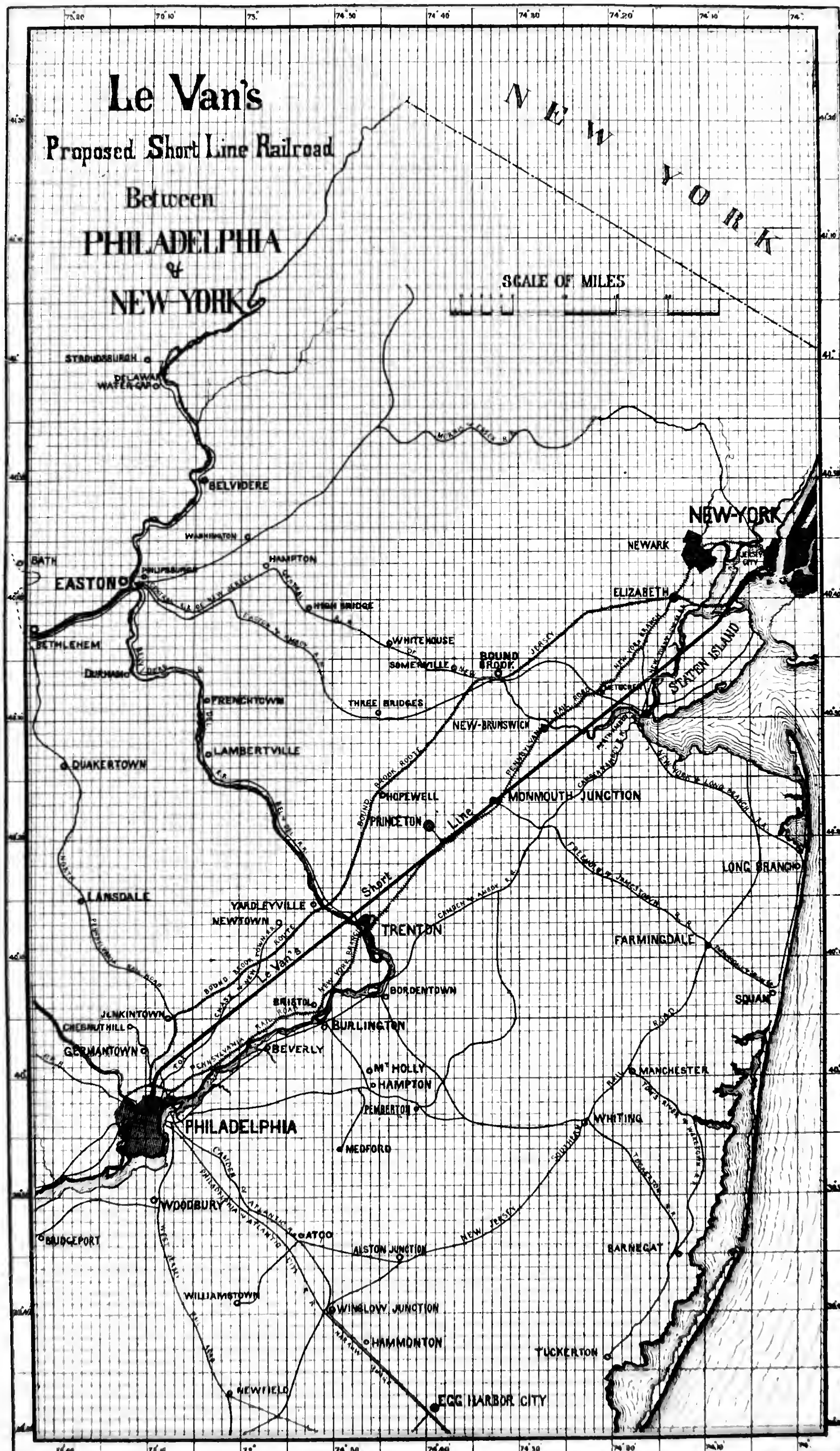
When a straight and comparatively level road-bed to connect these two great cities would represent a cash capital so moderate in amount the through traffic alone from city to city should assure, with proper management, large dividends on the investment.

To run ninety miles in one hour there are two problems to overcome—one geometrical, the other dynamical—the first as will be seen by the following map, Plate I, is solved by making the road a straight line of 80 miles: and by a judicious making up of trains, thereby reducing the dead-weight, the latter problem admits of solution.

The map, Plate I, shows the alignment of the present lines connecting the two cities, also that of an air line by which I propose to connect them which will not exceed 80 miles in length to Jersey City and can be made nearly level.

This proposed road to start at a point on Broad street, Philadelphia, at or near Arch, and by an underground road similar to that of the New York Central Railroad on Fourth avenue, New York city, to run out Broad street northerly beyond the Germantown Junction to about Bristol street (by so removing from public sight the locomotive and cars, their existence will almost be forgotten); thence in an air line nearly northeast in a direct line to Jersey City, it will cross the Philadelphia, Newtown and New York Railroad at or near Crescentville, the Delaware river about two miles above Trenton, and will run nearly parallel with the Pennsylvania on the north side, from Princeton to a short distance beyond Monmouth Junction, where it crosses the same, crossing the Raritan river about three miles below New Brunswick, also the Perth Amboy and Woodbridge Railroad, and the New York and Long Branch Railroad at or near Cutter's Dock; crossing Staten Island Sound to Staten Island, at or near Union Landing; passing near Chelsea and Graniteville to a point near Port Richmond Landing, about eight miles southwest of New York City Hall; thence across Kill von Kull to Bergen Point, and along the east side of the New Jersey Central Railroad, through Centreville and


75°20'
75°10'
75°
74°50'
74°40'
74°30'
74°20'
74°10'
74°
39°40'
39°30'
WILLIAMSTOWN
WINSLOW JUNCTION
HAMMONTON
TUCKERTON
NEWFIELD
EGG HARBOR CITY
R. R.
NARROW GUAGE
RAIL ROAD


Le Van's
Proposed Short Line Railroad
Between
PHILADELPHIA
&
NEW-YORK
NEW YORK
SCALE OF MILES
STROUDSBURGH
DELAWARE WATER GAP
BELVIDERE
WASHINGTON
BATH
EASTON
PHILLIPSBURG
HAMPTON
HIGH BRIDGE
BETHLEHEM
WHITEHOUSE
SOMERVILLE
BOUND BROOK
THREE BRIDGES
FRENCHTOWN
LAMBERTVILLE
QUAKERTOWN
NEW-BRUNSWICK
HOPEWELL
PRINCETON
MONMOUTH JUNCTION
LANSDALE
YARDLEYVILLE
NEWTOWN
TRENTON
Short Line
Le Van's
BORDENTOWN
BRISTOL
BURLINGTON
JENKINTOWN
CHESNUTHILL
GERMANTOWN
BEVERLY
Mt HOLLY
HAMPTON
PEMBERTON
PHILADELPHIA
MEDFORD
WOODBURY
BRIDGEPORT
ATCO
ALSTON JUNCTION
WILLIAMSTOWN
WINSLOW JUNCTION
HAMMONTON
NEWFIELD
EGG HARBOR CITY
TUCKERTON
BARNEGAT
WHITING
MANCHESTER
SQUAN
FARMINGDALE
LONG BRANCH
STATEN ISLAND
NEW-YORK
NEWARK
JERSEY CITY
ELIZABETH
NEW YORK & LONG BRANCH R.R.
FREEHOLD & JAMESTOWN R.R.
CAMDEN & AMBOY R.R.
BOUND BROOK ROUTE
NEW JERSEY
TOMS RIVER & WARETOWN R.R.
TUCKERTON R.R.
WEST JERSEY RAIL ROAD
CAMDEN & ATLANTIC R.R.
PHILADELPHIA & ATLANTIC CITY R.R.
NORTH PENNSYLVANIA RAIL ROAD
BELVIDERE DEL. R.R.
PENNSYLVANIA RAIL ROAD
MORRIS & ESSEX R.R.
NEW YORK BRANCH
75°20'
75°10'
75°
74°50'
74°40'
74°30'
74°20'
74°10'
74°
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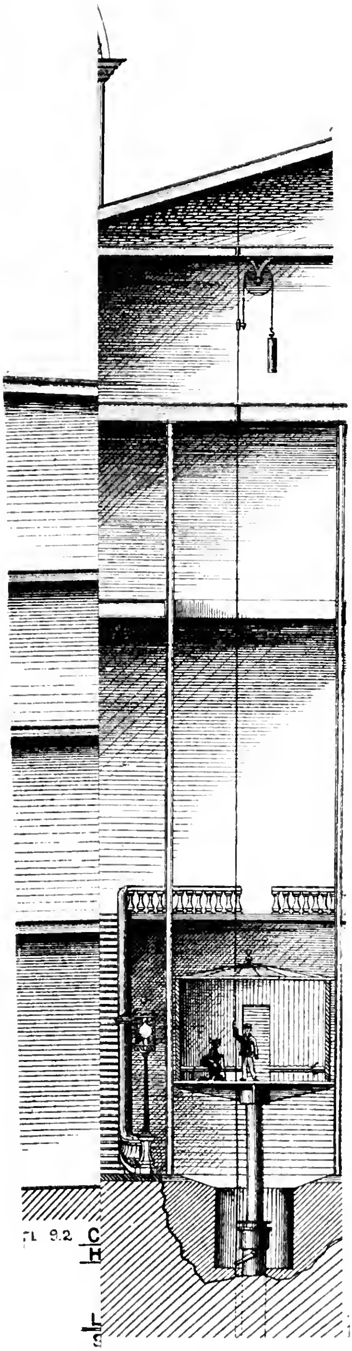
41°10'
41°
40°50'
40°40'
40°30'
40°20'
40°10'
40°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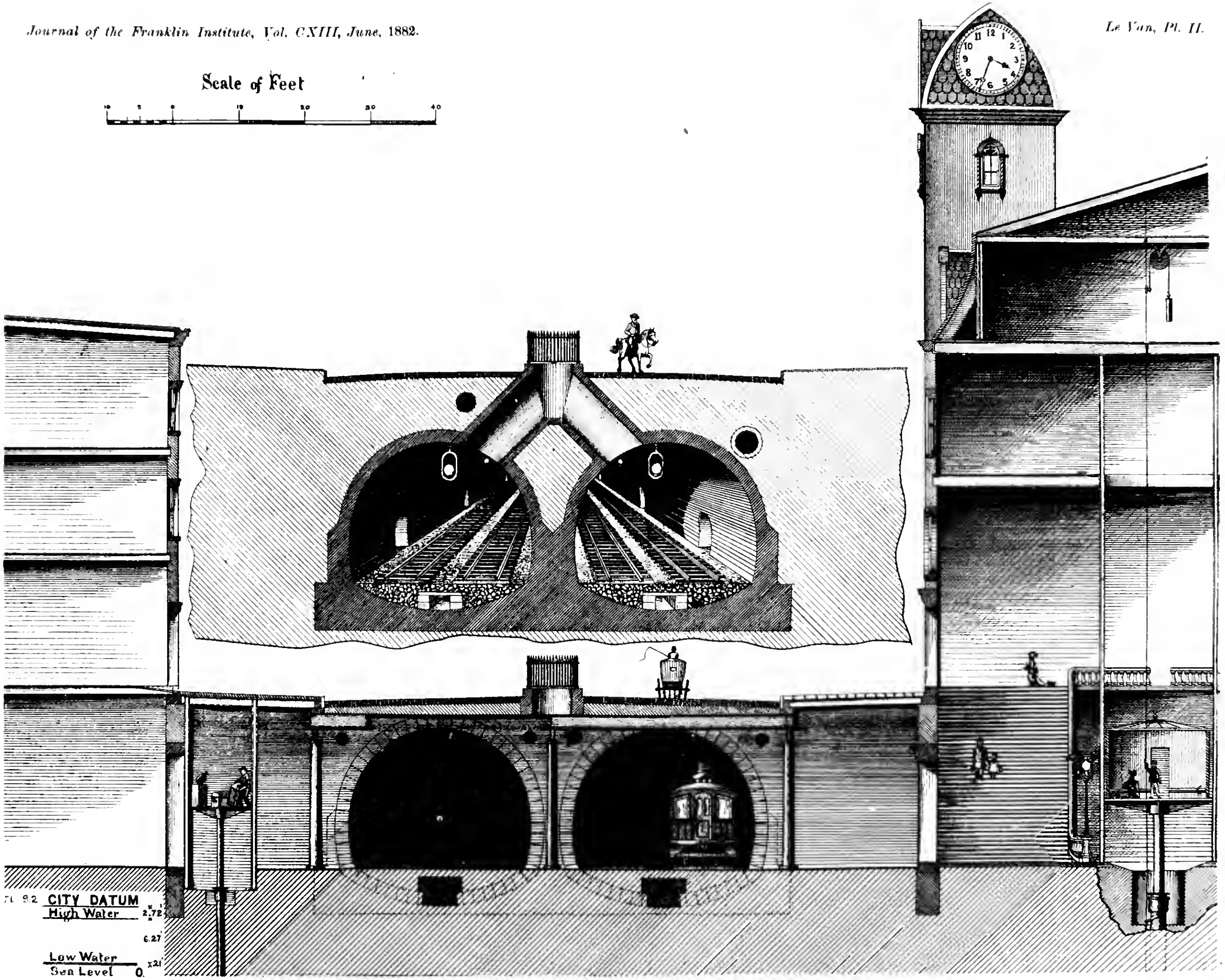

Scale of Feet
10 5 0 10 20 30 40
CITY DATUM
High Water
2.72
6.27
Low Water
Sea Level
0.

Saltersville, thence along the east side of the Morris Canal to Fish Point, and ending at a point between Ellis' Island and the New Jersey Central Railroad Station in Jersey City, one mile distant from the Battery, New York City, a distance of about eighty miles. None of the crossings to be on grade, and but three curves, and these all of more than 10,000 feet radius.

Plate II shows a section of the proposed station and road-bed at Broad and Arch streets, Philadelphia. The upper section shows a section of the road-bed at Broad and York streets, the difference in height of the two road-beds being the difference in grade between the two points.

Owing to the nature of the country through which it will pass the road-bed can be made nearly perfect. Such road should be lighted by the electric light along its whole length, the telegraph poles which average thirty to the mile could be utilized for supporting the lamps, thereby relieving the locomotive of its headlight and avoiding the necessity of lighting up the cars.

By this route a business man would be able to make a trip either way in one hour, and would be enabled to transact business and return the same day, and have several hours in his own counting-house, an important advantage to a large portion of our business community. By this means a very great object will be gained, for although the trip can now be made in two hours either way, it would be of double or treble importance to enable any one to make the journey in one half the time.

Each city has certain advantages different from those of the other, and it would be to the mutual interest of both could they be brought closely in connection one to the other. It is well known that both cities are growing very rapidly. New York now numbers over one million inhabitants and Philadelphia nearly the same. With the great increase in numbers, and with the growing tastes of modern times for greater accommodation and luxury, as evidenced in the prevailing costly style of residences, hotels, etc., we may be sure that improved railroad facilities will be demanded, and it is quite time to consider, if, indeed, the question is not already under consideration, how these may be accomplished.

I believe that the present roads will be wanted exclusively for freight, and that we require a direct road between the two cities for the accommodation of passengers only.

In laying out an important work of this kind, it will naturally be expected the best railways in the world will be looked to, as furnishing most important experience, and some cue as a guide. I have examined carefully some of our best engineering works, and studied those abroad, and am satisfied from all my investigations that there is no difficulty in building a connecting link between the two cities that will make to its stockholders a handsome return of the money invested.

The best evidence that there is a demand for fast speed is the fact that scarcely a day passes over but that on the Pennsylvania Railroad its "flying trains" must be divided up into sections and run at intervals of twenty minutes to accommodate those who are anxious to be carried at *high speed.*

In this age of steam and the state of the art there is no excuse for the lack of enterprise which fails to supply rapid transportation of such good quality and at so cheap a rate as not only to command the monopoly of the traveling community, but also, if possible, to entirely exclude rival and competing lines; that is to say, it would pay to build and maintain a line so perfect as to render the construction of additional lines a hazardous speculation, and so much better in all its appointments and details than existing lines as to draw the trade from the different points common to all, and to have it so well managed by continually increasing its accommodations as to secure the traffic from the districts already covered by existing lines; and to insure safety, speed and low fares, especially the latter, is what is now wanted by the traveling and business community, and what will be to the interest of railroad stockholders.

It has been found that the most secure profits in any business are those derived from low prices and a large consumption. On this principle it is considered good economy to obtain control of a route that can be run safely, rapidly and cheaply, even at the expense, if necessary, of a considerable outlay in the first construction.

In building a railroad there is a peculiar feature in regard to its economical running, in which it differs from the economical working of an ordinary manufacturer or machinist. A railroad must be as nearly perfect as possible when it is first constructed, as improvements made afterwards cost double, as for instance, the straightening of the Pennsylvania Railroad between this city and Lancaster. A manufacturer of cotton or woolen goods, or a steam engine builder may at any time most convenient to himself add expensive and more economical

machinery or buildings, and thereby produce a better or a cheaper article; but in building a railroad this cannot be readily done. If the road bed is not originally well laid out and constructed, and capable of being run cheaply and safely it can only be reorganized at a cost equaling that of a new line. All advantages must be secured, and the outlay made in the first instance, if the stockholders are to receive any advantage from the money they have invested.

RINGING BELLS.

By John W. Nystrom.

(Continued from page 376.)

In connection with the article on "Intonation of Chime Bells," published in the May number of the Journal, it is proposed to give the dimensions and weights of bells corresponding to each keynote in the eight octaves. For this purpose it is necessary to assume an average proportion of form, particularly that of the diameter at the bell-mouth to the thickness of the sound-bow, namely, $D:S = 1000:78$.

D = diameter of the bell in inches.

S = thickness of the sound-bow in inches.

n = double vibration per second, corresponding to the pitch of tone.

W = weight of the bell in pounds avoirdupois.

Diameter, $D = \dfrac{20592}{n}$. $\qquad \log.D = 4{\cdot}3136985 - \log.n.$

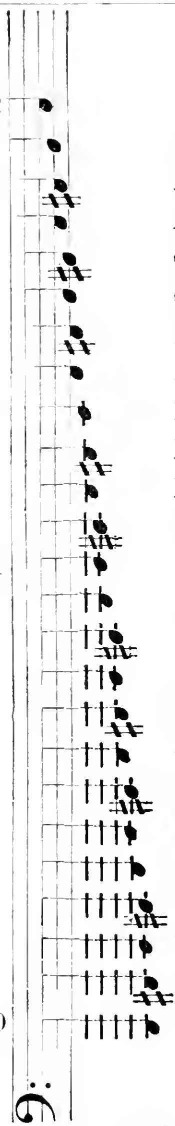
Weight, $W = \dfrac{204320000000}{n^3}$. $\qquad \log.W = 11{\cdot}3103144 - 3\log.n.$

The following tables of diameter and weight of bells are calculated from the above formulas, in which it is assumed that $S = 0{\cdot}078D$. For other proportions of S and D the diameter and weight of the bell will vary accordingly.

In old peals, all the bells are generally made of the same proportion, and even now some bellfounders hold to the old custom, probably for the reason that it is then easier to make the bell of correct pitch. When the proportion of S and D varies, as it should do for properly graduating the timbre in peals, it requires more knowledge of acoustics to make the bells right.

TABLE I.

Keynote, Diameter and Weight of Ringing Bells.

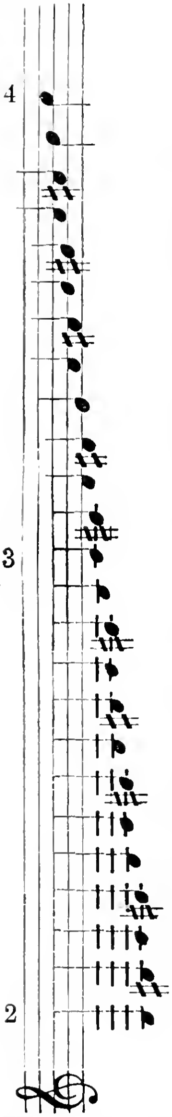


	Keynote.	Diameter, Inches.	Weight, Pounds.	Remarks on Bells and Musical Instruments.
2	C	156·	88,836	
	B	165·27	105,645	Great Bell of Nishni-Nov- [gorod.
	A♯	175·11	125,635	
	A	185·52	149,405	
	G♯	196·55	177,674	St. Ivan's Bell. Cast 1817.
	G	208·24	211,291	
	F♯	220·62	251,267	
	F	233·74	298,813	
	E	247·64	355,380	
	D♯	262·36	422,573	
	D	277·95	522,543	Great Bell of Moscow. [Cast 1736.
	C♯	294·50	597,656	
1	C	312·	710,688	
	B	330·56	845,285	Trombone Basso, lowest [note.
	A♯	350·21	1,005,100	
	A	371·04	1,195,240	
	G♯	393·10	1,421,400	
	G	416·47	1,690,300	
	F♯	441·24	2,010,100	
	F	467·48	2,390,600	
	E	495·50	2,844,900	Contra Basso, lowest note.
	D♯	524·72	3,380,600	
	D	555·93	4,020,400	Contra Fagotto, lowest [note.
	C♯	589·00	4,781,500	
0	C	624·	5,685,510	Bombardone, lowest note.

* St. Paul, London. Cast 1716.
‡ Bell of St. Peter's, Rome.
† Lincoln, Eng., 1834.
|| Bell of Montreal. Cast 1847.

TABLE II.

Keynote, Diameter and Weight of Ringing Bells.

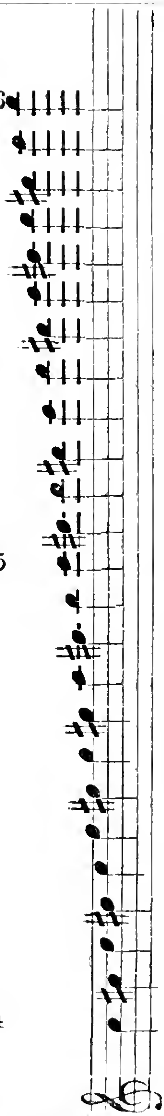


Keynote.	Diameter, Inches.	Weight, Pounds.	Remarks on Bells and Musical Instruments.
4 C	39·	1,388	
B	41·32	1,650	
A♯	43·78	1,964	
A	46·38	2,334	Standard tuning fork, 440 vib.
G♯	49·14	2,776	
G	52·06	3,301	Highest note on Bombardone.
F♯	55·15	3,926	
F	58·43	4,669	Tenor bell, St. Mark's Ch., [Phila.
E	61·91	5,552	Highest note on Contra Fag- [otto.
D♯	65·59	6,603	
D	69·49	7,852	Tenor bell, St. Stephen's Ch., [Phila.
C♯	73·62	9,338	Old Lincoln. Cast 1610.
3 C	78·	11,104	
B	82·64	13,206	
A♯	87·55	15,705	
A	92·76	18,675	Bell of Brussels, Belgium.*
G♯	98·28	22,212	Oxford, Gr't Tom. C't 1680.†
G	104·12	26,412	Bell of Cologne. Cast 1447.
F♯	110·31	31,409	York, England. C't 1845.‡
F	116·87	37,350	Bell of Erfurt. Cast 1487.‖
E	123·82	44,422	Bell of Westminster, Eng.§
D♯	131·18	52,822	Bell of Olmutz, Bohemia.¶
D	138·98	62,816	Lowest note on Clarinetto, B♭.
C♯	147·25	74,707	Lowest note on Clarinetto, A.
2 C	156·	88,836	

§ Lowest note on the Clarinetto C.
¶ Bell of Vienna, Austria.
§ Lowest note on Guitar.
¶ Bell of City Hall, New York.
¶ New bell of St. Paul's, London, 1881.

TABLE III.

Keynote, Diameter and Weight of Ringing Bells.



	Keynote.	Diameter, Inches	Weight, Pounds.	Remarks on Musical Instruments.
6	C	9·750	21·69	Highest note on C Flute.
	B	10·33	25·79	Highest note on C Clarinetto.
	A♯	10·94	30·67	
	A	11·60	36·48	
	G♯	12·28	43·38	Highest note on Clarinetto A.
	G	13·02	51·59	
	F♯	13·79	61·34	
	F	14·61	72·95	
	E	15·48	86·76	
	D♯	16·40	103·2	
	D	17·37	122·7	
	C♯	18·41	145·9	
5	C	19·5	173·5	
	B	20·66	206·3	
	A♯	21·89	245·4	
	A	23·19	291·8	
	G♯	24·57	347·0	
	G	26·03	412·7	
	F♯	27·58	490·8	
	F	29·22	583·6	Lowest note on Piccolo E flat [Flute.
	E	30·96	694·1	
	D♯	32·80	825·3	
	D	34·75	981·5	Lowest note on Piccolo C, [Flute.
	C♯	36·81	1167·	
4	C	39·00	1388·	

Table IV.

Keynote, Diameter and Weight of Ringing Bells.

Keynote.	Diameter, Inches.	Weight, Pounds.	Remarks on Musical Instruments.
8 C	2·437	0·339	Produced by the wings of a gnat.
B	2·582	0·403	
A♯	2·736	0·479	
A	2·899	0·570	
G♯	3·071	0·678	
G	3·254	0·806	
F♯	3·447	0·958	
F	3·652	1·140	
E	3·869	1·356	
D♯	4·200	1·612	Highest note of Piccolo E flat [Flute.
D	4·323	1·917	
C♯	4·601	2·280	
7 C	4·875	2·71	Highest note of Piccolo C Flute.
B	5·165	3·224	
A♯	5·472	3·834	
A	5·797	4·560	
G♯	6·142	5·422	
G	6·507	6·448	
F♯	6·894	7·668	
F	7·304	9·199	
E	7·739	10·84	
D♯	8·200	12·90	
D	8·686	15·34	
C♯	9·203	18·24	
6 C	9·750	21·69	

The Moscow great bell is the largest ever cast, being 272 inches in diameter and answers to the keynote D in the second octave, and weighs 432,200 pounds. It does not correspond exactly with the accompanying tables, for the reason that the sound-bow is $S = 0{\cdot}084D$.

The lowest note C, in the table, making $n = 33$ double vibrations per second, requires a bell of 52 feet in diameter, weighing 2550 tons, but by making the sound-bow $S = 0{\cdot}05D$, the same note would require a bell of only 400 inches, 33·3 feet, in diameter, weighing 430 tons. If the question was only to make a bell that would produce the lowest note C, making $n = 33$ double vibrations, without any other condition, the sound-bow may be taken $S = 0{\cdot}01D$, which would make the diameter only 80 inches, or 6 feet 8 inches, and the bell would weigh 1536 pounds. On the other hand, if the sound-bow is taken $S = 0{\cdot}1D$, which is sometimes done in bells, then the diameter for the same note would be 800 inches, or 66 feet 8 inches, and the weight of that bell would be 15,360,000 pounds or 6857 tons.

The above examples are only to show how the dimensions and weight of a bell can vary for the same keynote.

The preceding tables give the diameter and weight of bells of the most ordinary proportions.

[The discussion of this subject may be continued in a future number of the JOURNAL.]

Distribution of Energy in the Normal Solar Spectrum.— In the experiments which led Langley to the conclusion that the rays of light and heat coincide in intensity he found that the actual amount of energy which is required in a ray in order to make its presence evident through photography is less than $\frac{1}{10000000}$ of the energy which would be required, under the most favorable conditions, to produce a perceptible change in the most delicate galvanometer, by means of the most delicate battery. Langley's first paper presented the result of more than 15,000 galvanometer observations during a single year. In view of the rapid and extreme changes of atmospheric transparency many successive years would doubtless be required to secure the greatest possible exactness. He expects, by means of his observations, to arrive at a satisfactory determination of the actual amount of heat which the earth receives from the sun.—*Ann. de Chim. et de Phys.* C.

RADIO-DYNAMICS: UNIVERSAL PHYLLOTAXY.

By Pliny Earle Chase, LL.D.

Bonnet's discovery of the tendency in plant-growth to arrangement in cyclical spirals, seems to have been wholly empirical. The law of formation is simple, each of the phyllotactic numbers, after 1 and 2, being obtained by adding the two preceding terms of the series. Such simplicity might have suggested an early extension of the law into other fields of science, if it had been subjected to an earlier mathematical investigation, but for fifty years it was regarded as marking a curious, though inexplicable and perhaps accidental harmony.

In 1849, some of the professors and students of Harvard University became convinced that a law, which is so widely prevalent, must have some reason for its being. Chauncey Wright, in the *Mathematical Monthly*, showed that it represented a tendency to division in extreme and mean ratio, a tendency which distributes leaves and branches in the way that is most favorable for nourishment and growth. Peirce and Hill (*ante*, p. 141) extended the law to the planetary system. The orbital period of Uranus is very nearly $\frac{1}{2}$ of that of Neptune; Saturn, $\frac{1}{3}$ of Uranus; Jupiter, $\frac{2}{5}$ of Saturn; Asteroid 139, $\frac{2}{5}$ of Jupiter; Mars, $\frac{2}{5}$ of Asteroid 139; Earth, $\frac{1}{2}$ of Mars; Venus, $\frac{8}{13}$ of Earth; Mercury, $\frac{2}{5}$ of Venus.

Laplace's discussion of the curious relations among the satellites of Jupiter furnished a satisfactory explanation of an exact commensurability which is uncommon in natural phenomena. His explanation was grounded upon elementary laws of oscillation, which should be operative in molecular, as well as in cosmical movements. We may, therefore, be justified in looking for indications, in chemical atoms, of tendencies which are variously developed in the realms of time and space.

It is easy to detect exact harmonies of sound when there are only a few thousand consonances in a second, but in luminous or other æthereal vibrations the case is different. I have shown (Note 149, *Proc. Amer. Phil. Soc.*, xix, 600) that if there are two harmonic light waves, the slower oscillating 1670 times, while the swifter oscillates 1843 times, there may be more than 300,000,000,000 coincidences of phase per second, and yet mathematical tests, which are commonly

satisfactory, may indicate a possibility that the harmony is merely accidental. For this reason it is always desirable, when practicable, to study harmonic groups rather than isolated harmonies.

In the discussions of Prout's hypothesis I do not find that any one has tried to test its general probability by mathematical methods. Whatever doubts may be felt as to the value of any given test, in a solitary instance, may be removed when it is taken only as a means of estimating comparative probabilities. In making my comparisons I have sought to neutralize the effects of personal equation or bias, as well as of accidental or empirical coincidence, by adopting Gerber's method of grouping and Clarke's recalculation of atomic weights. In view of the *á priori* probability of tendencies to division in extreme and mean ratio, I assume that the ratio of probability to improbability, in each instance, is at least $\frac{1}{4}$ D : (T — O) ; D being the tested divisor, T the theoretical atomic weight or nearest exact multiple of D, and O the observed atomic weight, according to Clarke's table. I have added Rb and Tl to Gerber's list of monatomic elements, and Bo, Ta and V to his tri- and pentavalent-list.

If we designate the several probabilities by $p_1, p_2, \ldots p_{64}$, that of Li being p_1, and that of Yb, p_{64}, the formula for aggregate probability, $P_n = p_a\, p_b \ldots p_n$, when applied to the several groups and to all the elements, gives the following results :

RELATIVE PROBABILITY.

Groups.	Hydrogen.	Gerber.	Phyllotactic.
Monatomic,	32·083	1·	1·232
Tri- and Pentavalent,	1·	24·916	24·916
Di- and Tetratomic,	1·	5375080·	7780740·
Metallic,	89507·6	1·	67·267
Aggregate,	1·	46·637	5592·649
Mean,	1·	1·062	1·144

My surprise at finding that the aggregate evidence of harmonic influence is so much greater in favor, both of Gerber's divisors and of my own, than in favor of the hypotheses of Dalton and Prout, will, doubtless, be shared by many. The uniformity of the evidence, in the separate groups as well as in the aggregate, that the phyllotactic divisors are more significant than those which are only approximately phyllotactic, will awaken no surprise in the minds of those who have learned that cyclical undulations in elastic media must be harmonic.

After I had found the above relations, Dr. Thomas Hill suggested the application of similar tests to the surd divisors, $\frac{1}{2}(3-\sqrt{5})$ and $\frac{1}{2}(\sqrt{5}-1)$. These surds represent the division in extreme and mean ratio, towards which the phyllotactic ratios continually tend. Dr. Hill's participation in Peirce's investigations gave him an interest in other researches of a like kind. As he was inclined to look upon perfect commensurability, such as Laplace found in the Jovian system, as exceptional, he thought that the fundamental ratios, $S_1 = \cdot381966$ and $S_2 = \cdot618034$, might be more exactly represented in atomicity than any of their approximations. The thought had so much likelihood that I gladly undertook the needful calculations, getting the results which are given in the following table.

RELATIVE PROBABILITY.

Groups	S_2	S_1	H.	Gerber.	Phyllotactic.
Monatomic,	2·085	1·00	30402·95	947·66	1167·08
3 and 5,	1·000	2·12	516·46	12867·90	12867·90
2 and 4,	1·000	2102·03	103214·80	$5548(10)^8$	$8031(10)^8$
Metallic,	1·840	3·28	89507·60	1·00	67·27
Aggregate,	1·000	3816·79	$378(10)^{14}$	$17633(10)^{14}$	$21145(10)^{16}$
Mean,	1.000	1·14	1·82	1·93	2·08

There is evidence, therefore, in each of the groups as well as in the aggregate, of a tendency to division in extreme and mean ratio at the very beginnings of chemical activity. In the di- and tetratomic group the probable influence of S_2 is to the probability of accidental or unknown influence only as 1·446 : 1, or very nearly as 13 : 9. Even this ratio, however, is satisfactory as an indication of incipient action, and suggests the belief that in the "nascent state," in the "fourth state of matter," or in some other approximation to the æthereal condition, S_1 and S_2 may be found to have as great a degree of relative importance as belongs to the phyllotactic divisors in the above comparisons. Dextro- and lævo-gyration, in plant-growth, in cometary and satellite revolution, and in optical chemistry, may, perhaps, represent the opposite tendencies of the two surd divisors.

The aggregate probability of hydrogen influence upon atomicity is more than 9,900,000,000,000 times as great as the aggregate probability of the influence of S_1. The corresponding phyllotactic probability is more than 5592 times that of hydrogen, or more than 55,400,-

000,000,000,000 times that of S_1, the latter being more than 3816 times that of S_2. Some helpful hints may, perhaps, be drawn from the fact that the greatest superiority of S_1 and S_2, as well as of the phyllotactic and approximately phyllotactic division over the hydrogen division, is found in the artiad group.

Thus, in every direction, multiply the evidences of the importance in all physical researches, of paying heed to the blended sway of inertia and elasticity. The principles which I applied successfully, in 1863, to barometric estimates of the sun's mass and distance (*Proc. Amer. Philos. Soc.*, ix. 287, 288; x. 375, 376, foot note) have been abundantly exemplified in every field in which I have sought for their application, and now I find them at the threshold of material structure, where cohesive and chemical attractions first show themselves. I do not wonder, then, when I find that the virtual areas of synchronous planetary reaction, or the mean instantaneous areas which a particle at sun's surface *tends* to describe about any given planet, are approximately phyllotactic. They evidently vary as $\sqrt{mr}$, and the closeness of the phyllotactic approximations is shown in the following table. The common ratio, $\frac{3}{4}$, is twice the phyllotactic ratio $\frac{3}{8}$. The factor 2 is also phyllotactic, indicating, perhaps, the reciprocal influences of equal action and reaction upon which each of the harmonies is grounded.

	Harmonic areas.	Mean virtual areas		Difference.
α	40·256	Jupiter,	40·587	— ·331
$\beta = \frac{3}{4}\,\alpha$	30·192	Saturn,	30·063	+ ·129
$\gamma = \frac{3}{4}\,\beta$	22·644	Neptune,	22·675	— ·031
$\delta = \frac{3}{4}\,\gamma$	16·983	Uranus,	16·782	+ ·201
ε	1·000	Earth,	1·000	·000
$\zeta = \frac{3}{4}\,\varepsilon$	·750	Venus,	·749	+ ·001
$\eta = \frac{3}{4}\,\zeta$	·562	....	....	....
$\theta = \frac{3}{4}\,\eta$	·422	Mars,	·404	+ ·018
$\iota = \frac{3}{4}\,\theta$	·316	....	....	....
$\kappa = \frac{3}{4}\,\iota$	·237	....	....	....
$\lambda = \frac{3}{4}\,\kappa$	·178	Mercury,	·162	+ ·016

If earth were rotating with the speed which a coincidence of Laplace's limit, with the equatorial surface would give it, the time of rotation would be $2\pi\sqrt{r \div g} = 5073{\cdot}8$ seconds. Its coefficient of orbital rotation, therefore, is $86164{\cdot}1 \div 5073{\cdot}8 = 16{\cdot}982$, which is

equivalent to $\delta \div \varepsilon$. It is also nearly* equivalent to $a^{\frac{3}{4}}$, the nucleal radius in an expanding or condensing nebula varying as the $\frac{3}{4}$ power of Laplace's limiting radius. The locus of secular perihelion, or incipient rupture, for Uranus, is nucleally central between the mean loci of Jupiter and Neptune. I have often invited attention to the harmonic importance of the preponderating mass of Jupiter and the central position of Earth in the belt of greatest condensation. These renewed evidences of that importance lead me, through the doctrine of conservation of energy, to supplement Laplace's two laws of constancy by a third, viz.: *The sum of all the instantaneous virtual areas in a system will always remain invariable.*

The universality of photo-dynamic or radio-dynamic relations may be further illustrated by a new deduction of the identity of luminous and elementary gravitating velocity, which I first published in 1869 (*Proc. Am. Phil. Soc.*, xi. 103–107), but of which I gave foreshadowings nearly six years before. (*Ib.*, ix, 285, 357, 408; x, 269, *et al.*)

Coulomb's torsional formula may be applied to Sun's rotation, or circular oscillation, by taking Sun's equatorial semi-diameter, r_o, as the radial unit:

$$\int = \frac{m}{2} = \frac{W}{2} \cdot \frac{\pi^2 a^2 r_o}{gt^2};$$

$$\pi^2 a^2 r_o = \pi^2 l = gt^2; \; gt = v\lambda = \textit{velocity of light}. \qquad (1)$$

If Sun's apparent semi-diameter is $961''\!\cdot\!83$, Earth's semi-axis major $(\rho_3) = 214{\cdot}45\ r_o$; g at Sun's equatorial surface $= {\cdot}0000003909446\ r_o$; $v\lambda = \rho_3 \div 497{\cdot}827 = {\cdot}4307721\ r_o$. Therefore, by substituting in (1), $t = 1101875$ sec.; solar rotation $= 2t = 25{\cdot}506$ days.

Haverford College, March 6, 1882.

Equi-potential Curves.—M. Guébhard has studied the colored rings, which are produced in a mixture of acetates of copper and lead under a thin leaf metal, placed at an equal distance from vertical needles, which are attached to the poles of a battery of high tension. The curves appear to coincide with the equi-potential systems, which the formula of Kirchhoff gives for a similar distribution of electric poles on an indefinite plane.—*Chron. Industr.* C.

* The difference is 6¼ per cent. which corresponds very closely with the secular eccentricity of Jupiter.

A THERMOGRAPH:

A NEW APPARATUS FOR MAKING A CONTINUOUS GRAPHICAL RECORD OF THE VARIATIONS OF TEMPERATURE.

BY G. MORGAN ELDRIDGE.

[A Paper read at the Stated Meeting of the Franklin Institute, April 26, 1882.]

The instrument under consideration is a thermograph for recording the atmospheric temperature, the fluctuations of which are much less regular and more frequent than one who has not made a study of it would suppose. It records the temperature directly from the column of mercury in the tube of a thermometer by dots or perforations upon a sheet of paper previously ruled with degrees and hours.

Its principal parts are, as shown in Fig. 1 of Plate;

1st. A thermometer in the form of an ordinary mercury thermometer, but open at the top of the tube and having a wire entering the bulb and connected to one pole of a battery, the other pole of which is connected to the mechanism of the instrument.

2d. An upright cylinder revolving by clockwork, covered with a paper which is divided vertically into 24 parts by lines representing the hours, and horizontally by lines representing the degrees.

3d. A bar raised and lowered by mechanism driven by clockwork, furnished below with a needle entering the tube of the thermometer, and carrying a pencil—or preferably a point—driven forward by a small electro-magnet when the circuit is closed by the needle entering the mercury, and then making a mark at the proper place upon the paper and indicating the temperature.

The bar carrying the needle rises about half an inch from the point at which the needle leaves the mercury and then descends until the needle again touches the mercury, whether that in the meantime shall have risen or fallen, when the point makes its mark upon the paper and the bar again commences to rise.

This movement is accomplished by the mechanism shown in the drawing, of which only the wheel *E*, gearing into the rack upon the needle-bar, is shown in Fig. 1, but which is shown in full and upon an enlarged scale in Fig. 2, which is a top view. The two wheels *A* and *B* are moved by clockwork (not shown) and are constantly revolving;

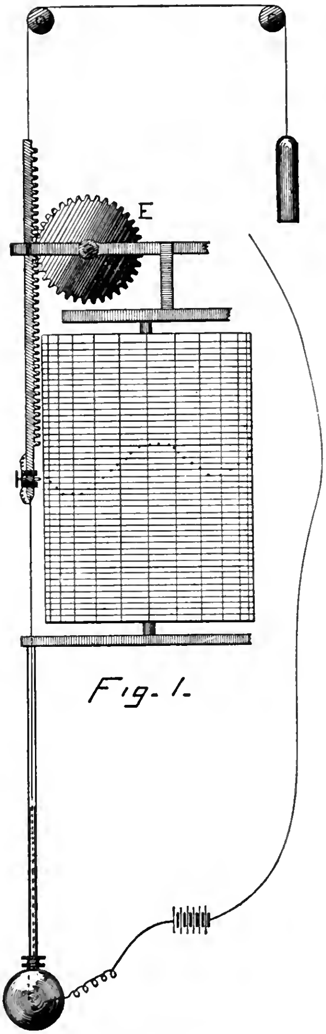


Fig. 1.

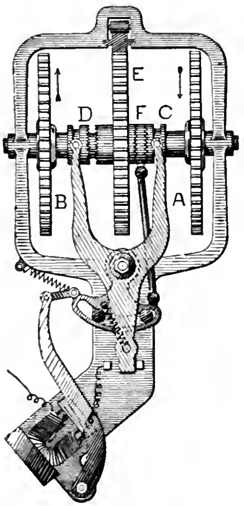


Fig. 2.

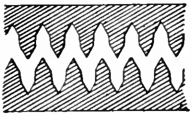


Fig. 3.

A NEW THERMOGRAPH.

in opposite directions, as indicated by the arrows. These wheels are not attached to the shaft upon which the wheel *E* is fixed, but are attached to sleeves which move without affecting that wheel except when they are joined to it by the clutches *C* or *D*. They are so geared that when the wheel *E* is joined to them its rim moves at the rate of half an inch per minute. Upon the shaft with the wheel *E* is also a loose sleeve *F*, which is free when the clutch *C* is not in action, but which moves with that wheel when that clutch is on.

The levers actuating the two clutches unite and move upon a common pivot, from which point they extend as an arm, which is capable of a lateral movement between two stops, bringing one or the other of the clutches into action.

Opposite to the wheel *E* the needle-bar passes through a guide which is furnished on the back with a small wheel taking the thrust of the gear and reducing friction. For a lower guide the needle-bar is furnished on each side with a rod parallel to the needle, and of nearly the same length. These rods are at such distance apart that they pass clear of the thermometer tube. They are not shown in the drawing, as they would lie directly in front of and behind the needle and tube.

The teeth of the clutches are partly V-shaped and partly square, or nearly so, as shown in Fig. 3; that is, they have slightly tapered sides but V-shaped points and bases, so that they enter freely, as entirely V-shaped teeth would do, and when in action they have no outward thrust. The V-shaped base strengthens the tooth and admits the point of the opposite tooth.

A very small spring on each side of the sleeve *F* holds it out of gear while the clutch *C* is off.

Beneath the clutch arm is a pressure spring, one end of which presses against the end of the arm and the other against a plate moving upon the same pivot with the arm, which plate also is capable of a lateral movement between its stops.

If this spring-plate is moved in either direction to its stop, carrying with it the base of the spring, the clutch-arm will be moved in the other direction and the clutch on that side will be brought into action; and if the position of the spring-plate with the base of the spring be reversed, the position of the clutch-arm will be reversed—that clutch will be disengaged and the other one will be engaged—the wheel *E* being moved and the needle-bar raised or lowered accordingly.

To the sleeve F is attached an arm which is connected by a draft rod to the spring-plate.

When the clutch C is in action—as shown in the drawing—connecting the wheel A with the wheel E and the sleeve F, raising the needle-bar, the arm of the sleeve F draws upon the spring-plate—moving to that side the base of the reversing-spring, which, when its base has passed the line between the pivot and the end of the clutch-arm, presses that arm to the other side, disengaging that clutch, loosing the sleeve F, engaging the other clutch, and reversing the motion of the needle-bar, which now descends.

The length of the arm on the sleeve F is such that when the needle-bar has risen half an inch the spring-plate is moved over, and the clutch-action is reversed.

When, by descending, the needle is brought in contact with the mercury and a circuit is made, the large electro-magnet, thus vitalized, attracts its armature, which is attached to a lever connected with and drawing upon the spring-plate, and moves the base of the reversing spring to that side, changing the position of the clutch-arm and reversing the action of the clutches and the movement of the needle-bar, while at the same time the recording point upon the needle-bar is, by its electro-magnet, driven into the paper and the temperature is recorded upon the scale.

The sleeve F, being loose, yields to the movement of the spring-plate, and is afterwards held by its clutch, and acts as before.

The action of the large electro-magnet is supplemented by that of a spring drawing upon the same side of the spring-plate, whose strength is such that it is not quite sufficient of itself to overcome the thrust of the reversing spring, but whose force is greatest when that of the electro-magnet, by reason of its distance from its armature, is least, the greatest possible portion of the work being thus put upon the clock-work and the least upon the battery.

This spring aids the electro-magnet, but does not in anywise reduce the effect of the reversing spring in holding the clutch to its work; so long as the base of that spring is unmoved its action is unimpaired. The resistance of these springs occurs only during the ascent of the needle-bar, which is, therefore, counterpoised to excess, and the resistance and the motion are thus rendered uniform. By reason of the form of the clutch-teeth before described there is no outward thrust upon the clutches while in action, and hence the reversing spring

requires only to be strong enough to throw the arm over and to shift the clutches. The stop of the clutch-arm next the electro-magnet is an insulated plate to which the battery-wire leading from the magnet is connected, so that as soon as the arm has left the stop the circuit is again broken, although the needle may for a short time remain in contact with the mercury; the recording point is at once withrawn, and thus makes upon the paper a single perforation which must be a true record of the position of the mercury in the tube, unaffected by friction or other disturbing cause, since this action must always take place at the moment of contact of the needle with the mercury, and these dots or perforations are repeated at the end of each interval of time required for the needle-bar to ascend and descend the required distance, which will be about two minutes with the wheel-motion designated.

The graduation of the scale upon the paper must correspond with the movement of the mercury in the tube of the thermometer as accurately as the graduation of the scale of an ordinary thermometer corresponds with the movement of the mercury in its tube.

If but one instrument of this sort is to be made this is very easy, the rate of motion is ascertained, a scale is made to fit it, and the paper is ruled to that scale.

In all thermometers heretofore made the scale has been made to fit the tube, but if more than one of these instruments is to be made it becomes necessary, or at least very convenient, to have one set of ruled papers that will fit all the instruments, and it then becomes necessary to reverse the practice and to make the tubes to fit the scale.

The rise and fall of mercury in a thermometer depends upon the proportion between the diameter of the tube and the volume of mercury in the tube and bulb, and while it is possible to construct these parts in such proportion as to obtain proximately a given motion, it is not possible thus to obtain it exactly.

The tube and bulb are made in separate parts, as shown in Fig. 1, of such size that when the tube is thrust half way into the bulb the volume of mercury filling the tube half way at 32° Fahrenheit is as nearly as may be properly proportioned to the diameter of the tube. If now there be found too much motion the capacity of the bulb is diminished by thrusting the tube further in, and *vice versa*, and the proper height of mercury at 32° for that purpose is marked upon the tube.

Mercury exposed to the air will slowly form a coating of oxide upon

its surface. To prevent this a small quantity of glycerin or of oil free from oxygen is placed in the thermometer tube above the mercury. If, notwithstanding, the oxide shall accumulate to an inconvenient extent the observer in charge of the instrument will remove the thermometer from its place, and will put the bulb in warm water until the oxide is floated off. He will then supply the loss with pure mercury, determining the proper quantity by immersing the bulb in broken ice, when the mercury column should stand at the mark for 32°.

The whole apparatus, except the thermometer itself, can be enclosed and so protected from the weather and dust, while the thermometer is exposed to the air below.

The system is equally applicable to a barometric record, in which case, on account of the small range of motion, the needle-bar is connected to a lever, thus increasing the range of the record.

ELECTRICITY.

By A. E. Outerbridge, Jr.

[Abstract of a Lecture delivered at the Franklin Institute, March 10, 1882.]

The subject of our lecture is one which offers unusual attractions at the present time, not only to the close student of science, but also to men of every profession or trade. The rapidity with which new discoveries in electrical science have followed each other of late years, together with the numerous practical and economical applications of the force to all sorts of industrial pursuits, and the prescience of still greater advances to come in the near future, has sufficed to render the subject an exceedingly popular one, and to lead many people to believe, whether truly or not, that electricity is the "coming force," which is to prove man's most useful servant, and is even destined, perhaps, to supplant steam power for many mechanical purposes, just as steam superseded human and brute force.

There is, I think, another explanation for the fascination attending, and the popular interest shown in, the study of electricity, which has little to do with its practical phase. I refer to the element of apparent mystery attaching to many of its phenomena.

There would seem to be a natural bias in many minds towards the mysterious, which not infrequently exhibits itself in an extraordinary

development of credulity, giving credence to the puerile teachings of self-elected professors of so-called supernatural agencies, known by various cabalistic names, such as "Psychic Force," "Odic Force," "Animal Magnetism," "Mesmerism," "Spiritualism," etc., but these various "isms," unlike the agency or force which will engage our earnest attention, have not been able to bear the light of careful searching investigation, nor have they been productive of any practical or useful advantage to man. Rather have they tended to befog the weak intellect and to create a doubt in the ill-balanced mind of the stability of nature's laws and the unity of her beneficent purposes, which all true scientific research tends so clearly to reveal.

Electricity as *an entity* was one of the earliest known of nature's agencies, having received its baptismal name more than two thousand years ago, and its sponsor was no less a person than one of the seven wise men of Greece. As *a science* it is the youngest of all her children, and is not yet out of its long clothes, although it is an amazingly precocious infant, having recently learned to talk, and we are astonished to find not only that its voice is strong and lusty, but also that its adaptability for all languages is without limit, reproducing the soft mellifluous tones of the Italian or Spaniard with the same ease that it does the harsher gutturals of the Teuton, the extraordinary syllabic enigmas of the Russian, or the peculiar labials of the "heathen Chinee." So admirable, indeed, are its linguistic accomplishments that it echoes the multitudinous tongues of men with the perfection of one "to the manor born," thus claiming recognition as an infant prodigy without an equal. It is difficult to realize that this youngest electrical child, which we call the "Telephone," is scarcely six years old; for its voice is now heard in all enlightened lands, and it has even become a very necessity of our modern civilization.

Although Thales made his famous experiment with amber more than five hundred years before the Christian era, his observation remained unheeded for twenty centuries. During the long years of the Roman wars, and later, when the Goths and Vandals were overrunning Europe, spreading terror and anarchy in their path, and precipitating the dark age of ignorance and superstition, we can well imagine that the trivial thought of catching feathers with a piece of amber would have no attractions for men, and so we find that it was not until the beginning of the seventeenth century that any further notice was taken of Thales' Amber Spirit. Nevertheless, the little

seed of investigation which had lain buried for so many centuries was neither dead nor wholly forgotten, and from this tiny grain of knowledge has grown the vast tree whose roots reach out to the ends of the earth, and under whose wide-spreading branches thousands of working men now find their daily occupation and sustenance. It is my design to trace out, very rapidly, and of necessity very imperfectly, the gradual development of this germ, to follow the ramifications of its roots, to show the luxuriance of its foliage, and finally to point out a few of its most promising blossoms, some of which are just budding into fruit, while others, though they may seem to flourish for awhile, are doubtless doomed to fall to untimely decay.

The science of Electricity is now passing through a critical period of its development, analogous to that which its sister sciences, heat and light, experienced some years ago, when a famous coterie of eminent investigators (prominent among whom was our countryman, Benjamin Thomson, afterwards Count Rumford) dissected the chrysalis, cleared away the cobwebs which surrounded it, overturned the corpuscular theory, and, by a magnificent series of experiments, proved that heat and light are not material substances, which may be squeezed out of a body, like water from a sponge, but that they are merely "modes of motion" of little molecules of matter.

There are in effect two theories of electricity now extant; the older one, although actually repudiated by practical electricians, still lingers in our text-books, and is, unfortunately, still taught in many of our schools. The other is the new science which has been the outcome of the labors of such men as Sir Wm. Thomson, Professor Maxwell, Dr. Siemens and many others of eminence and ability.

The first of these two sciences, which must, we hope, soon be eradicated from our school curriculum, is founded on the theory that electricity is a fluid, or that there are two fluids, commonly called positive and negative or vitreous and resinous. We must discard the old notion of electric fluids or currents flowing along a wire, as water flows through a pipe, and learn to realize that there is no passage of any material substance whatever when the circuit is closed on a wire in Philadelphia and the click is heard almost instantly in the receiving instrument in New York.

We no longer believe, as did our ancestors, that there is any transfer of material substance along the beams of light and heat which proceed from the sun to the earth. We know that there is simply a transfer

of motion from particle to particle of the intervening, highly attenuated medium, called for the want of a better name, the "luminiferous ether."

If you cast a stone into a pond and watch the ripples radiating outwards, growing larger and larger, until they strike the opposite shore, you do not imagine that the actual particles of water which were displaced by the stone have traveled to the other side of the pond. You know, on the contrary, that they have given up their motion to their nearest neighbors and these again have passed the impulse to their neighbors, and so on until there has been a transfer of motion through the whole of the water and the wave strikes the distant shore. So we believe that when a body is "charged with electricity" its molecules are thrown into a new state of vibration, not very different in character, perhaps, from that which shows itself as light in the little filament of carbon, enclosed in a vacuum bulb, which we will cause to become brilliantly incandescent by means of the electric force obtained from the dynamo-machine operated by the engine in the laboratory.*

Let us then once and for all discard the antiquated notion that electricity is a fluid and regard it henceforth as a form of energy or a mode of motion; we will then find that many hitherto vague and confused ideas in regard to its character may be reduced to definite and clear terms and that the most delicate phenomena of electricity may be measured with mathematical accuracy and precision.

Those of us who have gained clear ideas of the nature of matter and its properties will find little difficulty in conceiving the possibility of a vibration of molecules, under electrical excitation, or rather of such vibration *causing* electrical excitement. We know that the molecules constituting even the most dense solid substances, like lead or platinum, are not in actual contact, but that they are free to move, and, in fact, are constantly and forever vibrating with enormous velocities within certain boundaries. It is even believed that if this molecular motion should stop, "matter, as we know it, would cease to exist."

We know that the mere change in temperature of a few degrees is sufficient to visibly alter the length of a bar of iron or other metal, and we can easily realize that, as the temperature of all bodies is incessantly changing, its molecules are forever in motion from this disturb-

* The lecture room was illuminated with Edison and Maxim incandescent lights.

ing cause alone. We know that the change in condition of a substance from the solid to liquid and thence to the gaseous form is a visible expression of the increased motion of its molecules under the influence of heat vibration. We know that sound, heat and light, have all been resolved into "modes of motion," and now we believe that electricity also is henceforth to be included in the study of the laws of motion. Thus we see that the most widely separated phenomena and the most complex of nature's operations emanate from one common cause, showing a "unity in diversity" which is in itself a strong and logical argument in favor of the new theory.

There is one point which investigators in this field of research too often fail to fully recognize, viz.: that you can no more create electricity from nothing than you can create steam-power without the expenditure of fuel; for, although the various forces of nature are mutually interchangeable, they are so nicely balanced and controlled by unchanging law, that man with all his ingenuity cannot add to, or subtract one tittle from, the sum total of force in the world; the most he can ever hope to do is to utilize these ready-made forces for his special purposes, with the least waste possible.

The theory that electricity is a form of energy, which can only be developed by an equivalent expenditure of work of some kind or other, is quite a modern notion, and as it becomes more fully understood it will tend to eradicate many of the vague ideas and fallacious expectations which now prevail in regard to the future possibilities of utilizing electricity for lighting, heating, driving machinery and countless other useful purposes for which it seems so well adapted.

The general acceptance of the idea that electricity is a form of energy and not a form of matter has been somewhat retarded, hitherto, by the lack of adequate terms in which to express its dicta, for scientists do not coin new standard words as rapidly as the mint coins its new "standard dollars," which are, however, false measures of value, even though they may be of true standard fineness. This difficulty is gradually becoming eliminated, and the obsolete expressions which convey the idea of fluids and currents are giving place to more exact definitions; thus, the word *potential* is used to express the difference between a body in a state of electrical tension and another in its normal condition of molecular equilibrium; it does not commit us to any preconceived theories, and possesses another great merit in that the difference of potential (or electro-motive force, which is an equiva-

lent expression) between two dissimilarly electrified substances may be accurately measured and their comparative values may be stated in terms which we can all understand, and may even be reduced to the ordinary mechanical unit of work, the foot-pound.

There are other terms, which have been devised, to express the units of intensity, resistance, etc., with which the student must familiarize himself; their elucidation does not come within the legitimate scope of a "popular lecture," which should aim, first, to awaken interest in the subject of which it treats, and then to point the way in which it should be pursued to its ultimate goal. The student of electricity will find a permanent investment for his intellectual capital, never failing in interest, for the fund of knowledge is growing larger day by day.

In view of the modern developments in electrical science only a foolish man would venture to define the boundaries of its future progress, for if we allow our imagination the smallest liberty in the contemplation of such subjects we are sure to be almost startled at the vast possibilities for practical and useful applications of this force which suggest themselves; and yet, when we consider the actual accomplishments of the searchers in this field during the past few years, the most daring flights of fancy seem hardly more than natural sequels to events which have already outstripped all calculation.

It is not unlikely that some of my hearers may remember the years when Morse was wearily striving to obtain a small grant of money from an unwilling Congress, to enable him to lay his experimental telegraph line from Washington to Baltimore. He was derided as a crazy visionary, and Congress was ironically advised, by jeering wiseacres, to appropriate money from the public coffers to project a telegraph line to "the man in the moon." Most of us, doubtless, well remember the time, not very far distant, when the idea of an Atlantic cable was generally regarded as an impracticable and absurd scheme, yet there are now "more than seventy thousand miles of sub-marine cable," and the overland wires threading the earth to-day are long enough, if they should be stretched in a straight line, to reach our satellite!

The present magnitude of the telegraph business is a favorite theme for writers on these subjects, and has been well set forth by Mr. Preece in his lecture on the "Recent Wonders of Electricity." It is matter of history that on the day of President Lincoln's funeral no less than

seventy thousand words were transmitted from Washington to New York in the short time of six hours and a half, and this was before the use of the quadruplex system, by means of which four messages are now sent over one wire, in different directions, at the same time, and it was also prior to the invention of the automatic system, which has increased the speed of transmitting words more than one hundredfold.

The telephone, in its practical form, is not yet six years old, and yet there is scarcely a business community of any importance in this country or in Europe to which it is a stranger.

The electric light is no longer a scientific curiosity, and the manufacture of the plant used in its production has grown into a large industry, giving employment to hundreds of workingmen, and representing millions of dollars capital invested.

The art of the electro-plater is another vast industry, and the statistics of the amount of gold and silver annually consumed in the process of gilding and silvering the baser metals seem almost incredible, especially when we reflect that a single grain of precious metal will cover several square feet of surface.

The admirable "block system" of operating railroad trains, which has greatly reduced the danger of accidents from collision, calls in the aid of this force, or rather depends upon it for its very existence, and even trains themselves have been propelled in Europe for several months past by this force alone. The idea of employing electricity as a motive power for machinery is by no means a novelty, but it has assumed new importance in the light of the recent improved methods of developing and utilizing the force economically.

It is a stupendous thought that our great natural curiosity, Niagara, is freely offering to our use its mighty arm, which is strong enough to turn every loom, operate every machine shop or other manufactory throughout this broad land, and that this may be accomplished by the intervention of means which we already possess of converting the headlong force of the cataract into the quieter channel of dynamical electricity, or, as we might otherwise say, *by changing its mass motion into molecular motion.* The calculations made by Sir Wm. Thomson, Dr. Siemens and other eminent scientists, show that this is no mere poetical fancy or impracticable idea; it is certainly quite within the bounds of rational discussion, if not of actual possibility, at the present time. It has been shown that a copper cable of no unwieldy dimensions would carry one thousand horse-power of electrical energy a distance

of one hundred miles without a very enormous loss, and it is even predicted that the time will come when our factories will be operated during the day, and our shops and houses illuminated at night, by the giant power of Niagara or some other less water-fall nearer home.

It would seem a curious and beneficent provision of nature that when the coal and wood, with which we are as yet well supplied, shall have become comparatively scarce and dear, the future race of men may find their substitute in water, not merely as a source of mechanical power, but also of light and heat.

It may be that our descendants will look back with curiosity to the time when their ancestors discussed with caution the possibility of thus utilizing the waste forces of nature, and they may well wonder at our extravagance in consuming black diamonds in our furnaces in order to obtain therefrom a mere modicum of their stored energy in the form of mechanical power.

As an ever watchful detective against our common enemies, fire and thieves, this agency has proved its fidelity time and again, never compounding with felons, and, if properly attended to, never failing to perform its duty.

By the simple addition to the ordinary ship's compass of two platinum pins, forming the terminals of a wire connected with a little battery and a call-bell, the captain of the vessel may retire to rest in security, knowing that if the man at the wheel allows the ship to wear away more than the fixed allowance the little bell will sound its note of warning in the cabin or stateroom; it is even possible to make the arrangement automatic, so that the same controlling force shall open steam valves which operate the mechanism of the rudder, and so the vessel may be kept on one undeviating course without the further intervention of human agency. The same principle has been applied to steam and water gauges, to sound a timely warning in the office of the large manufacturer when the pressure of steam in the boiler exceeds a certain limit or the level of water falls below a safe point.

The doctor and surgeon have found electricity a most valuable auxiliary in their efforts to alleviate human suffering, and new fields of usefulness in this direction are almost daily opened up to the profession.

In the physicist's sanctum electricity reigns supreme, for it is equally adapted to perform the coarsest work and to assist in the most refined investigations.

At the various meteorological stations throughout the country, the finger of electricity is at work, day and night, recording the hourly and even momentary changes of atmospheric conditions, and the same agent transfers these records to the central bureau in Washington in order that the mariner and the farmer may be forewarned of the approach of tornadoes, rain-storms or biting frost.

At the government arsenal may be seen a beautiful apparatus for recording, by a little spark of electricity, the velocity of projectiles, thus affording a means of measuring the explosive force of different samples of gunpowder. The whole distance the bullet is allowed to travel is only a few feet and the time consumed in its flight is inappreciable to the ordinary perception, yet the record made by the spark (which passes from a vibrating tuning fork to a cylinder of metal coated with lamp-black, revolving at a known speed), tells at a glance the exact time consumed, which is so infinitesimal that its expression in decimal fractions of a second requires a prefix of several ciphers.

At a recent scientific entertainment in London luscious fruits, which were grown by the aid of the electric light, were served to the guests. I dare say, many of you have read with interest Dr. Siemens' account of his experiments in electrical horticulture, the practical possibilities of which are, no doubt, more apparent to the inhabitants of that land of perpetual fog than to our more fortunate selves, where the sun is so generous of his beams and so constantly "shines free for all."

The astronomer, whose gaze is fixed on the heavenly bodies, does not scorn to avail himself of terrestrial electricity, and he, too, has found this force an invaluable aid in his most abstruse researches.

Applying the principle of varying resistance of metals at different temperatures to the passage of electricity he has recently been enabled to construct an apparatus for measuring the heat of the stars,* a sort of celestial thermometer "which will promptly indicate a change of less than one fifty-thousandth of one degree Fahrenheit, and will even measure these extremely minute amounts of heat and compare their differences with each other, though the whole quantity involved would produce no change whatever in the most sensitive thermometer."

These are but a very few of the useful applications of this ubiquitous agent, which seems to be the only one of man's possessions that he can employ in two places at practically the same time. To indicate the various other directions in which electricity may be utilized in the

* Professor Langley's *Bolometer.*

future would require both a vivid imagination and a careful sense of discrimination, and would occupy far more time than we have to devote to such speculations. We can only allude, in conclusion, to the probability of telegraphing without wires, which has already been done experimentally, and to the more remote possibility of transmitting the power of vision to a distance through the peculiar electrical properties of selenium when acted on by light.

Whether these beautiful experiments, which are the very quintessence of refinement in physical research, may produce practical results or not, they will undoubtedly serve as indicators to future generations of the intellectual and scientific attainments of the human mind in our day, and each new step forward enlarges the scope of our mental vision and smoothes the path for those who are to come after us.

As we stand on our vantage ground to-night and look back over these recently explored regions, we have reason to feel proud of all that has been accomplished and to rejoice that we are living in an age of such activity and progress in useful and ennobling scientific pursuits.*

Pulverizing Rocks by Dynamite.—Major Lauer claims that his method of pulverizing rocks in the beds of rivers, by exploding dynamite on their surface, leaves them in a condition to be removed by the current. When the cartridges are inserted in drill holes, the rock is broken into large fragments, which must be removed mechanically and often at great cost.—*Ann. des P. et Chauss.* C.

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* The technical portion of the lecture, which is not reported herein, was illustrated with apparatus, both of historical interest and of recent invention. In the former list was Dr. Benjamin Franklin's frictional electrical machine, by means of which he sent electric flashes across the Delaware river, between Philadelphia and New Jersey, through a submerged cable, one hundred years before the invention of the Morse Telegraph.

An original working model of Bains' electro-chemical telegraph; also, an original Morse apparatus, all of which are preserved in the museum of the Franklin Institute.

In the latter category were induction coils, Geissler & Crookes tubes, Toepler-Holtz machines, etc., contributed by Messrs. Queen & Co.

A Brush dynamo-machine, operated by a six-horse power engine which supplied arc and incandescent lights, the Maxim lamps being contributed by the Company and the Edison lights by the Baldwin Locomotive works, where they have been in practical operation for some months past.

AN ESSAY ON MECHANICS AND THE PROGRESS OF MECHANICAL SCIENCE—1824 TO 1882.

By FREDERICK FRALEY, LL.D.

One of the Original Members of the Franklin Institute and President of the American Philosophical Society.

[A Paper read by title at the Meeting of the American Society of Mechanical Engineers, Philadelphia, April, 1882.]

With an introduction by COLEMAN SELLERS, M.E., Passed Vice President of the American Society of Mechanical Engineers.

[A meeting of the American Society of Mechanical Engineers in the lecture room of the Franklin Institute in Philadelphia, suggested to President Thurston the desirability of a paper on the part played by the Franklin Institute in the progress of the mechanic arts in America, and he so advised the Local Committee. It happens that the present Treasurer of the Franklin Institute was one of those who organized the Society in the year 1824, and he has been not only a member ever since, but he has at almost all times been engaged in the management of the Institution. It is natural to turn to one who has taken part in the active work of the Institute for fifty-eight years for information, so it comes that the writer asked his friend, Frederick Fraley, LL.D., to prepare the paper herewith presented. The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, has, through its more than half a century of existence, done much to earn its full title. While mechanic institutes started at the same time have long since passed out of existence, this Institute, founded on the broad basis of uniting all who are to give and obtain instruction, has grown and prospered. Its prosperity, and the work it has done, afford a useful lesson. It has never confined its membership to mechanics only, but while its constitution provides that its Board of Management shall hold a majority of manufacturers, it draws to itself all who are in any way interested in the progress of the Mechanic Arts, and this bringing together of men of varied interests on the common ground of seeking for information, has had the best possible result. Mr. Fraley has repeatedly told the writer that he owes to the Franklin Institute the greater part of his education, and much of his success in life. In asking for this contribution to the history of a scientific society, it is

hoped that the information given may be of use, not only to kindred societies, but even to one that is more limited in its range of membership than is the case with the Franklin Institute.]

I have been a member of the Franklin Institute since its organization in 1824, and this is the only right I have to present this paper for your present session.

When I recall my early remembrance of the mechanic arts in this city in the days of my youth, and compare them with what I see around me now, it is difficult to realize the change or to make any satisfactory comparisons. What was true of the condition of mechanical science in this city at the beginning of the present century was more so, of every other part of the United States, and comparatively so, of the continent of Europe and of the island of Great Britain. The active inventive genius of the English and French people in the latter part of the 18th century was beginning to develop the germs of the great machines that have since been perfected, and have, it may almost be said, revolutionized the world. The laws of motion and the application of the mechanical powers had become to some extent known, and chemistry was rising in importance and aiding in carrying on the processes which were to subdue the rude natural materials which were to supply the mechanic with the means for carrying on his labors.

What was needed was the establishment of some kind of school that should bring together intelligent men of different professions and occupations, and by mutual support and study increase the amount of useful knowledge, and divide and distribute it to form new combinations and to make the growing wealth of such acquisitions available for the common good. It was for these ends that the Institute was founded, and its history truly records the growth, advancement and present state of mechanical science in the world. As it was the first really educational mechanics' association in the United States, it has continued to hold its rank as "*primus inter pares*."

Let us consider for a moment with what we had to deal in its origin. There were a few small and isolated workshops in which mechanical trades were carried on with rude and imperfect tools, and perfection depended more on the strength and skill of the hand of the artisan and on the acuteness of his eye, than on any clear mental perception of what he was doing or that the doing of it could be reduced to anything approaching scientific rules.

I recollect my visits to some of the well-known work-shops of those days, and have seen Patrick Lyon striking vigorous blows on his anvil, Oliver Evans in his foundry, Jacob Perkins in his fire engine manufactory, and the Messrs. Sellers in their then wonder-working wire works, turning out the marvelous hand and machine cards. It was indeed a great privilege to be permitted to visit those establishments, for they were the pride of their proprietors, and were not to be entered by all with impunity.

But with the establishment of the Institute came a new phase of these things. There had for some years been a sort of mechanics' club, which zealously guarded additions to its membership, and was so much attached to ancient mysteries, that it mercilessly black-balled all who attempted entrance by the shibboleth of modern ideas.

So it happened that Samuel V. Merrick was excluded from this venerable, close guild, and he resolved to form an institution on a more liberal basis and with broader views, and he joined to himself a few congenial spirits, who went manfully to work and called a public meeting of Philadelphia citizens, which was largely attended, and which enthusiastically adopted the plans of the founders, and gave us the great institution in whose Hall you are holding your present meeting.

True it is that Benjamin Franklin founded in Philadelphia, in the year 1743, the American Philosophical Society for the promotion of useful knowledge, but mechanical knowledge in that day did not hold the place it now does.

While Franklin followed a mechanical trade and did much handicraft work to make his printing attractive and profitable, he soared to higher heights and became philosopher, statesman and political economist, by which he earned his great and glorious name.

Philadelphia has always been distinguished for the beauty and excellence of its mechanical productions.

In the earlier part of the present century she was the point of attraction for purchasers from all parts of the United States.

It was therefore eminently fitting that a great mechanics' educational institution should be established in that city.

The plans for it were comprehensive and struck down to the very roots of what was needed.

It took hold of the grown and skillful men of all trades, blended them with merchants, lawyers and scientists, put them all in personal

and friendly contact for the communication and diffusion of all they knew, and then made provision for the education of the young in a high school, to be characterized by the teaching of what would be useful in practical life.

It established the first regular school in the United States for instruction in mechanical drawing, and has kept it in successful operation for more than fifty years. In the first year of its existence it had courses of lectures on mechanics, chemistry, architecture, natural philosophy, and volunteer lectures on particular arts and trades. These lectures were attended by numerous classes, and made a great impression on the public, which increased the power and promoted the success of the Institute. This success gave it courage to hold an exhibition of American manufactures, the first held in the United States; and the specimens of American skill then presented were numerous, well made and indicated a good basis on which future progress and perfection could be built up. Such exhibitions have been continued at convenient intervals, and have marked the march onward of mechanical skill. By the division of the leading members into standing committees on all the principal objects of the Institute, and by the regular meetings, the whole machinery of instruction was put in motion, and the results were soon apparent. It gathered a valuable library and cabinets of models, minerals and manufactured products, and thus soon became an Institute of Technology of the first rank, and that rank it continues to maintain at this day. It seems to be like the fable of the eagle continually renewing its youth, and as the old veterans have fallen from the ranks, the young and vigorous have filled up vacant places with enlarged knowledge and fired with the same confidence and hope.

Another aid given by the Institute to the development of mechanical science is found in its JOURNAL. This publication has been continued monthly for more than half a century. It contains a full *resumé* of American patents up to the period when the Patent Office commenced the publication of its reports. It contains, besides, many original essays and copious republications of articles on mechanics from foreign journals. By exchanges, it has largely contributed to build up the library which has now a large store of wealth of technological knowledge.

In the way of original research the Institute can point with pride to its investigations of the value of water as a motive power; of the

causes of explosion of steam boilers, of the strength of materials, of dynamo-electric machines, and to its examinations and reports upon many hundreds of new inventions.

These have brought into permanent notice many of the active members, who unselfishly devoted themselves to the elucidation and dissemination of the great truths which adorn the fields in which they labored. To name them all would be difficult indeed, for their number is not small. Prominent among them, however, are Samuel V. Merrick, William H. Keating, Robert M. Patterson, Matthias W. Baldwin, Rufus Tyler, Benjamin Reeves, Isaiah Lukens, Franklin Peale, Asa Whitney, John C. Cresson, William Sellers, Joseph Saxton. One of the early chiefs was Alexander Dallas Bache, who closed his life of devotion to science as superintendent of the United States Coast Survey, a work which gave full play to the highest forms of accurate and useful applications of mathematical and mechanical knowledge.

In this connection, also, I must strive to pay just tribute to the merits and zeal of its professors, among whom we find in its early days, R. M. Patterson, William H. Keating, William Strickland, Franklin Bache, John K. Mitchell, Walter R. Johnson, John C. Cresson, James B. Rogers, and John F. Frazer. Their successors are numerous and worthy, and they in the present days are upholding the honor and sustaining the reputation of this mother of mechanical institutes of our country. As she was the first of these really educational institutions, the model which she presented has been closely followed, and the benefits which she gave to the mechanics of Philadelphia are now largely shared by the craftsmen in all parts of our widely extended territories, by the labors which such kindred institutions have fully and freely bestowed.

My object in the preparation of this paper was to attempt to show by the history of the Institute, some illustration of the progress of mechanical science for the last sixty years, and to show by the gleanings I have made from this vast field, amid the active labors of a different line of life, the impressions made upon my mind by the truly marvelous triumphs of mechanical skill, which have claimed my admiration and remembrance. If I shall add an hour of pleasure to your meeting I shall be amply repaid for its preparation.

I cannot close it, however, without attempting to bring before you, in contrast, what I saw of machinery and its progress in my youth,

and what I see now. I shall refer first to the supply of water to the city of Philadelphia.

Then she was just emerging from the use of wells and hand-pumps, and the rude steam engines placed near the Schuylkill river at Chestnut street and at the base of the marble building in the Centre Square at Market and Broad streets, and the modest basin eighty feet at its summit, and sixty feet in diameter, were the wonder and boast of the citizens. The pipes for the distribution of the water were wooden logs bored by hand, and it was not until after the establishment of the Institute that iron pipes were cast in this country. A few had been imported from England, and this fact became a political war-cry, and nearly revolutionized the city government. About the year 1822 the water-power works were established at Fairmount, a transfer of the steam-power having previously been made to that point, a large Boulton & Watt engine, having taken the place of the original engines. The Boulton & Watt engine was a beautiful piece of work, and marked a well-defined phase in mechanical engineering. For a short time by its side worked a high pressure engine of great simplicity and with few parts, invented and constructed by Oliver Evans, the great American mechanic, who is probably the inventor of the use of steam under high pressure, and who deserves a high place in the pantheon of inventors. Recollect that then no other large city in the United States was supplied with water by machinery, and that the representatives of city corporations came to study and imitate our example. Now every large city boasts of its water supply arrangements, and the steam and water powers exhibit the perfection which study and experience give. Compare the locomotive engine of the present day with the embryo of Oliver Evans, or the machine of Blenkinsop, or the English machines of Stephenson, or the first one of Baldwin, with those which are now daily turned out of the hundreds of the great workshops of the world, and notably those of our own country, and you will again realize the progress of your special science.

Look at the manifestations of the same progress from the rude spinning jennies and mules of Arkwright and Crompton, to the contents of a modern cotton or woolen mill, and marvel at the mechanical fingers which spin and weave the massive sail cloth or carpet, and the gossamers which clothe the queens of kingdoms and of fashion.

Look at the machines and tools of precision, and see how they have contributed to bring about so much perfection.

In this connection, also, the introduction of standard sizes and uniformity in the several parts of machines have tended to great economy and practical usefulness.

How much has been gained by the adoption of the United States standard for screw threads, for which we are indebted in a large degree to the ingenuity and experience of Mr. William Sellers. The stand taken by the Institute to prevent a forced adoption of the French metric system has been of great use in guarding us from a violent and unnecessary revolution in the weights and measures of our country. These are so identified with all our measurements, and the welfare and protection of society and property that to disturb them seems to me to be as criminal as the burning of the great library at Alexandria.

Upon such a survey of the progress of mechanical science as it has fallen under my observation and study, I feel that the men of this century have well performed their duty, but they must keep their hands to the plough and not be content with what has been accomplished. They must cherish the spirit of brotherhood, be ready and willing to communicate and spread all useful knowledge. They must aid in keeping up the great educational institutions of the country, especially in their scientific and technical departments, and so give to the present and coming generations the advantages and accumulations of all the wealth of knowledge which has been obtained by the labors of genius and perseverance, and provide more abundantly for their increase.

Telegraphing in Mid-Ocean.—M. Menuisier proposes to attach to the submarine cables, at distances which are about equivalent to a day's sail, supplementary cables reaching to the surface of the water and sustained by luminous buoys. A ship, in passing near the buoy, could put the wires of its apparatus in communication, one with the wire of the buoy, the other with the buoy itself, which would serve as a ground wire. The circuit would thus be completed and the buoys being all numbered, communication could be immediately established with the central station. The inventor believes that he has provided against the danger of breaking the cables by tempests and all other objections that are likely to be urged, and he has satisfied able navigators who have examined his plans, that they would be likely to succeed.—*Chron. Industr.* C.

DEVICE FOR INCREASING THE DYNAMIC EFFECT OF THE PULSATIONS OF DIAPHRAGMS AND THE LIKE.

By WM. B. COOPER.*

Abstract of remarks made at the stated Meeting of the Franklin Institute, April 26, 1882.

Within the past few years the impact of sounds acting either upon diaphragms or other sounding bodies rigidly connected with other similar bodies at a distance, or first converted into galvanic impulses, and then reconverted at a distant station into sound waves, have come to play so large a part in the mechanism of our civilization that any invention promising to enlarge the effectiveness and usefulness of these devices naturally attracts attention; this fact has induced me, in compliance with request, to briefly set forth a device of mine having as its principle the augmentation of the above-mentioned comparatively feeble impulses, by adding to them, through the agency of a coefficient of friction, an increment derived from an auxiliary power.

When a cord is passed over a revolving pulley it is well known that there is a pull upon one side proportioned to the character of the surfaces in contact and the pressure upon them; this pull is due to the friction of the surfaces upon each other and increases approximately (if not exactly) in the same ratio as the pressure; now, if the pulley is loose upon the shaft and we draw upon a cord passing over it we have the same force exerted at the other end of the cord minus the friction at the shaft; if, however, the pulley is attached to the shaft and is rotating towards the end drawn upon, then the result at the other end will be the force applied, plus the amount derived from the friction upon the surface of the pulley. This is the principle of my device. To one end of a wire or band I attach a diaphragm or other pulsating body and then give a half turn or several turns around a drum or pulley; to the other end may be attached a lever having a point adapted to the indentation of sheet-metal passed under it. In this form I have termed it the "Phonodynamograph," and my experiments have already resulted in embossing brass of the thickness of writing-paper by the impact of the voice upon a diaphragm of the

* Mr. Cooper exhibited a model illustrating the principle of his invention.

size used in the phonograph. The increased dynamic effect, however, may be used in various ways; for example, it may be made to operate a stouter diaphragm, or even an armature of some weight, to and from the poles of a magnet, as in the telephone, and thereby produce more powerful galvanic impulses and consequently a louder tone, and the diaphragm, or an armature at the receiving station, by this device, may be made by means of a lever and a spring, to create pulsations of greater amplitude in a second diaphragm and thus increase the sound; this last may be accomplished in another way which the limits assigned for this article will not permit me to describe.

INFLUENCE OF PULLEY DIAMETER ON THE DRIVING POWER OF FLAT BELTS.

By Robert Grimshaw.

[Abstract of a paper read at a meeting of the Franklin Institute held April 26, 1882.]

Most of the experiments reported have appeared to show that the diameter of the pulley has no influence on the coefficient of friction or the driving power of belts. Dr. Grimshaw described some experiments in which belts were made to slide over fixed pulleys, and announced as a result that the thicker the belt the greater the influence of pulley diameter upon its driving power, and that the smaller the pulley the greater the loss of actual contact surface (proportional to the size of pulleys) due to the ridges formed in thick and stiff belts that are sharply bent. The speaker claimed that nearly 1000 experiments made by him warranted the rejection of Morin's law.

The following tests made with a single "fulled" leather (partly tanned) belt made by Schultz Belting Company, St. Louis, are given as examples of tests made by Dr. Grimshaw's assistant, Mr. John E. Hilleary, on the day of the meeting. The pulleys were turned cast-iron, little worn and but slightly crowning, being Cresson's standard.

The first column gives half the weight of the belt; the second column, the weights added; the third, T_2, the tension on the slacker of the two sides: the fourth column, the weight added to cause slipping; the fifth, T_1, the weight on the taut end; the sixth, the grip or difference in tensions; the seventh, the ratio of T_1 to T_2; the eighth, for

convenience of reference, the natural logarithms of the ratios; and the last column, the coefficient of friction according to Morin's formula,

$$C = \cdot 733 \log. \frac{T_1}{T_2}.$$

The averages of the ratios and of the coefficients of friction at different tensions, are given for each pulley. It shows in this case a difference in the coefficient of friction, of 24·06 per cent. in favor of the larger pulley.

Single Fulled Leather Belt, 4 inches wide, 180° contact.

	½ Weight of Belt—lbs.	Added Tension. lbs.	Total Tension Light End—lbs. T_2.	Weight added. Taut end—lbs.	Total Weight. Heavy End. T_1.	Grip—lbs.	Ratio, $\frac{T_1}{T_2}$.	Log. Ratio $\frac{T_1}{T_2}$	Coef. friction $= \cdot 733 \log. \frac{T_1}{T_2}$
36-inch Pulley.	1·50	5	6·50	12·	13·50	7·	2·072	0·316390	·2319
	1·50	10	11·50	22·	23·50	12·	2·043	0·310268	·2274
	1·50	20	21·50	43·	44·50	23·	2·116	0·325516	·2383
	1·50	40	41·50	88·81	90·31	48·81	2·176	0·337659	·2475
	1·50	60	61·50	126·81	128·31	66·81	2·09	0·320146	·2346
						Av.	2·099		·2359
18-inch Pulley.	1·50	5	6·50	10·87	12·37	5·87	1·903	0·279439	·2048
	1·50	10	11·50	20·	21·50	10·	1·869	0·261609	·1917
	1·50	20	21·50	37·	38·50	17·	1·79	0·252853	·1853
	1·50	40	41·50	81·81	83·31	41·48	2·01	0·301247	·2208
	1·50	60	61·50	110·81	112·31	50·80	1·81	0·257679	·1888
						Av.	1·874		·1982

RECENT IMPROVEMENTS IN THE MECHANIC ARTS.

An Improved Mercury Pressure-gauge, which employs the Bourdon spring, is designed to obviate the trouble arising from the tendency of the tube connecting the boiler with the gauge, to become clogged by the lodging of sediment within, by the rusting of the pipe, or by the freezing of water condensed therein. The same trouble is likely to arise in the passages of the Bourdon spring. It is essential, therefore, that the Bourdon spring be connected with the boiler in such a manner that it can be ascertained at any moment whether the steam has free passage therein and free access to the spring; and also that the danger of freezing of the condensed steam is made as slight as possible. The improvement consists in combining with the steam supply pipe, a pipe connecting it with the passages of the Bourdon spring and adapted to contain mercury or other pressure-transmitting medium, and upon which the steam is brought in direct contact. A passage communicating with the outer air extends from the end of the steam passage, and has a suitable cock or valve for opening and closing the same.

A Novel Device for Underground Electric Communication comprises a conduit or main, laid beneath the road-bed in the street, with service nipples at desired points in the conduit. These nipples are provided with a laterally upwardly extending chamber, the access or opening of which extends under the curb and up to a level on the sidewalk. The wires pass in coils over cleats in the mouths of said openings where they can be conveniently tapped when desired.

A Novel Receiver for Telephones is provided with a diaphragm made of cork. This diaphragm has a central button of carbon attached to its centre. A reduced flexible extension of the magnet core is in contact with the piece of carbon. The molecular vibrations of the magnet are communicated to the carbon and through the same to the diaphragm.

An Improved Device for Lubricating Car-axles consists of a brass or bearing provided with a chamber or recess on its lower side, or that next the axle. A passage-way is provided between said chamber and a pump, which is operated by the vertical vibratory

motion of the axle-box, which tends to lift oil to the chamber. This pumping device consists simply of a vertical tube, having the end which projects into the oil reservoir made flaring and provided with a check-valve opening upwardly. The oil will be further assisted to rise in the tube by the partial vacuum created in the said chamber by the revolution of the axle.

A New Adjustable Piston comprises two parts, the meeting ends of which are cylindrical in form. One of the ends is arranged to move longitudinally in a recess in the other part, and has a screw-spindle taking a bearing on said part. A screw-threaded locking-sleeve serves to lock the two parts together.

A Recent and Important Improvement in "individual call" systems of telephone alarms is announced. It comprises a clock mechanism at the central station which is normally at rest. It carries a revolving electrode. Another electrode, adjustable by hand, is arranged concentric with the axis which carries the revolving one. The catch, which holds the clockwork normally at rest, carries a contact point whereby the battery-current can be thrown upon the line momentarily when the catch is operated. Each subscriber's station has a clock mechanism, an electro-magnet, and armature arranged in the main circuit for controlling the clock-work. A grounding or branch circuit is used. Two electrodes are employed, one being a stationary arm and the other revolved by the clock-work. A spring-impelled train of gears and an electro-magnet and armature are arranged in said grounding circuit for releasing the alarm. The revolving arm-electrodes upon being released (the central station by its catch and the subscriber's station through its magnet in the main line) by a single impulse generated upon the main line, will each rotate synchronously for one revolution, during which that subscriber's station, and that only, whose stationary electrode lies in the same direction as that to which the adjustable electrode of the central station has been set, will have its ground-wire circuit closed and the armature and magnet therein attracted, thereby releasing the spring impelled alarm.

F. B. Brock.

Washington, D. C., May 12, 1882.

Causes of Magnetic Variation.—F. Folie discusses the hypothesis, which is accepted by many geologists, that the earth is composed of a solid crust, together with a mass, more or less fluid, beneath the crust. Hopkins had previously calculated the precession and nutation which would result from a fluid nucleus, but his conclusions were not satisfactory, and Folie gives new reasons for rejecting them. He thinks that the crust would partake, to some extent, of the disturbances of the interior, and that the only way in which the exact latitude of a place could be found would be by taking observations when there is no disturbance by nutation, or by distributing the observations equally over the whole period of nutation. He further supposes that if the solid shell of the globe oscillates about the fluid nucleus, the friction, which results from the pressure of the nucleus upon its envelope during this movement, should constantly engender a great quantity of electricity, which may be one of the principal causes of terrestrial magnetism. The gradual cooling of the interior ought, according to this hypothesis, to be shown by a diminution of the constant of nutation, and a like diminution of magnetic intensity.—*Bull. de la Soc. Roy. de Belge.* C.

Electric Torsion.—Hughes has arrived at the following conclusions: 1. An electric current polarizes its conductor and the molecular magnetism can be converted into an electric current by a simple torsion of the conductor. 2. It is only by the rotation of its molecular polarity that an electric current is produced in consequence of torsion. 3. The passage of a current through an iron or steel wire is spiral. 4. The direction of the spiral depends upon the kind of current and on the magnetic polarity of the wire. 5. A natural magnet can be arranged with spiral molecular polarities, and consequently electric currents of opposite kinds may both produce a like spiral. 6. Torsion of the polarized molecules may be produced by a forcible transverse or longitudinal stretching. 7. The rotation, or the movement of molecules, produces audible sounds. 8. These sounds may be increased or diminished, or even destroyed, by the same means which produce molecular rotation. 9. The same effects having been obtained by three different methods, it cannot be said that they are due to a simple change or weakening of polarities. 10. Heat, magnetism, continuous electrical currents, mechanical stretching, vibrations, all exercise a marked influence upon this class of effects.—*La Lum. Electr.* C.

Sensible Evidence of the Roundness of the Earth.—In a late session of the Helvetic Society of Natural Sciences, Prof. Dufour spoke of the change which images that are produced upon a great expanse of water undergo, in consequence of the roundness of the earth. If the luminous ray from an object strikes a tranquil lake, in a nearly horizontal direction, the image is made upon a convex surface and appears smaller than the object itself. Prof. Dufour arrived at these conclusions by calculation, but he supposed that they could never be verified on account of the difficulty of finding a lake sufficiently calm over a broad extent of surface. His friend, M. Forel, however, informed him that he had seen such images in the lake of Geneva, and that they appeared exactly as the calculation had indicated. Prof. Dufour subsequently found that the days upon which such observations are possible are by no means uncommon, but the images can often be seen on lake Leman, especially if one has a spy-glass at his disposal. After having looked for a moment, the roundness of the earth becomes visible as plainly as that of a bowl that is held in one's hand.—*Les Mondes.* C.

Identity of Spectral Rays in Different Elements.—The question of identity of spectral rays is one of great interest; as it is very improbable that a simple molecule should be capable of taking part in the immense variety of vibrations which are indicated by the complex spectrum of iron or titanium, we may suppose that these substances are formed of heterogeneous molecules and that some of those molecules are common to numerous elements. Moreover, the supposed identity of certain rays has furnished Lockyer with an argument in favor of a simple theory of chemical composition from one or a small number of primitive elements. Angstrom gives seventy lines, as common to two or more substances. Young found that fifty-six out of the whole number are double or triple, seven more doubtful, and only seven appear decidedly simple. Liveing and Dewar find that even the last class are more refrangible in some elements than in others. Hence they draw a conclusion which is opposite to that of Lockyer.—*Ann. de Chim. et de Phys.*

[The well-known experiment of swinging balls suspended from a horizontal cord shows that cyclical vibrations are modified by each member of a harmonic group, so that Lockyer's theory would not be shaken by slight differences of wave length when the same element is combined with different elements.] C.

Viscosity of Gas.—Brooks concludes from his experiments upon the viscosity of gas in a nearly perfect vacuum, that some of the molecules may traverse more than a hundred times the mean distance of their ordinary course, and that they may also acquire a corresponding augmentation of the mean velocity before being stopped by collisions. From some of the phenomena he infers that the gaseous and ultra-gaseous states succeed each other in an insensible manner, so that at a given moment we may be able to perceive, at the same time, the phenomena which are produced by the gas and by the ultra-gas. The experiments of Tresca and Andrews have shown that the same fact is true in the passage between the solid and the liquid, and between the liquid and the gaseous states.—*Ann. de Chim. et de Phys.* C.

Powerful Electric Discharges.—De la Rue and Müller have experimented upon the electric discharge, during the past six years, with a voltaic battery of constant current. It is based upon the Daniell cell, but a solid electrolyte, which is insoluble in water or chloride of silver, replaces the soluble, so that the porous cup can be dispensed with. By a combination of 14,400 united elements in series they have produced a variety of interesting results. If we admit that a cloud, at a very great distance, acts essentially as a simple point, when a flash of lightning is produced, either between two clouds or between a cloud and the earth, the potential which is necessary to produce a flash of a mile's length would require 243 units, equivalent to the combination by the experimenters of about 3,500,000 cells.—*Ann. de Chim. et de Phys.*

Detection of Malic Acid.—Two Italian chemists have found that when a solution containing malic acid is boiled with a few drops of sulphuric acid and a small quantity of bichromate of potash, a strong odor of ripe fruit is developed. They have applied this property to the examination of the precipitate which is produced by chloride of lime, in an alcoholic solution of various organic acids. The precipitate is withdrawn from the solution, decomposed by dilute sulphuric acid, and the filtered liquid is boiled with a small quantity of bichromate of potash. If the liquid remains yellow, succinic acid is indicated and can be detected in the usual way by means of perchloride of iron. If the liquid grows green, but is odorless, there are indications of citric acid. The greenness accompanied by the odor of ripe fruit shows the presence of malic acid.—*Mo. Mag. of Phar.* C.

Electric Light in Building Operations.—The use of the electric light in England for illuminating the works of building and destruction preparatory to rebuilding is increasing. The large machine shop of Messrs. Fowler, in Leeds, having been burnt, the proprietors immediately telegraphed the agents of the Brush machines to furnish their apparatus, in order to help them in clearing away the rubbish during the night. Forty-eight hours after the despatch was received, the Brush lamps were burning over the ruins.—*La Lum. Electr.* C.

CORRESPONDENCE.

What a Patent Grants.

To the Editor of the Journal of the Franklin Institute:

Sir—A paragraph in Mr. Howson's book, noticed on another page, induces attention to an error, popular among patentees, that their patents give them—as on their face they say they do—a "right to make, use and vend" the article or machine described in the patent; the fact that they do no such thing is a fruitful source of trouble, and its discovery furnishes one of the special grounds of complaint against the Patent Office and its administration.

It constantly happens that a man holding a patent which professes to give him this right, assumes that this profession is true, and his surprise and disgust, and not infrequently his loss, are proportionate to the faith which he puts in this assertion, under the seal of one of the highest departments of the government of his country.

In point of fact, the patent does not give him any right whatever—either exclusive or otherwise—either to make, use or vend the thing named; if he did not have an entire and absolute right to do so before he applied for a patent, he has none such by reason of its issue to him. What the patent does grant him is the right to exclude others from making, using or vending the thing covered by the claims of his patent—only that and nothing more—and that is a very different thing from what the patent says, and from what he believes because his patent says it.

There will probably be, before long, some legislation on the subject of patents, and it is submitted that it would be well to have the form of the patent amended, so that it shall say just what it means, and that he who runs may read understandingly.

Of course those who are correctly informed concerning the law of patents know very well what the phrase implies, but patentees as a class are, and of necessity always must be, composed of men who have no knowledge of patent law, and who therefore suppose that the words mean what they say, and so are led to error and brought to loss.

G. MORGAN ELDRIDGE.

Philadelphia, May 8, 1882.

Book Notices.

REISSUED PATENTS: Comments on the Decision of the United States Supreme Court in the case of Miller *vs.* The Bridgeport Brass Company. Practical effects of the Decision and its Warning to Inventors. By H. Howson, Sr. Philadelphia: T. & J. W. Johnson & Co. 1882.

In this volume the author has presented a clear statement of a much troubled and very troublesome question, and has brought plainly before the notice of such of the public as are interested in patents and patented articles the evils which have arisen from the abuse of the privilege of reissue and the inconveniences which are likely to result from a change of law and practice so radical as that which may follow from the decision which forms the text of his discourse. Upon the ground both of the benefits and the injuries likely to accrue the volume is well worthy a careful reading by those concerned in the questions involved, and to those who have the legislative power to sustain the one, and to prevent the other, the suggestions contained in the little book are worthy of consideration.

The right of reissue is a good thing—in many instances affording to an inventor the only possible means of protecting his unquestionable rights—like many other things, good in themselves, however, it has been so much abused that as matters stand at present, or at least as they stood before this decision and some others which clearly foreshadowed it, it is doubtful whether, on the whole, more evil than good has not resulted from it. Some legislation is necessary and will probably grow out of this case, but it will require high skill and rarely good judgment, so to frame it, as to avoid grave injustice in some cases.

The strictures of the author upon the practice of "no patent, no pay," are eminently just, and might fairly have been even more severe.

The evils arising from it can scarcely be overrated—if the subject were once understood by the inventing public they would cease—for the practice itself could no longer exist. A system more demoralizing to the solicitor and destructive to the inventor could scarcely be devised. G. M. E.

THE STUDENTS' GUIDE IN QUANTITATIVE ANALYSIS, intended as an Aid to the Study of Fresenius' System. By H. Carrington Bolton, Ph.D. New York: John Wiley & Sons, 1882.

Many who remember the articles entitled "Schemes of Analyses executed in the School of Mines, Columbia College," contributed several years ago by the author, to the *American Chemist*, will gladly welcome this book. These articles, which the untimely end of the *American Chemist* left in an unfinished state, are now collected and completed in the volume before us. In regard to the purpose of the book we cannot do better than quote from the preface as follows:

"Fresenius' system of instruction in quantitative chemical analysis is placed in the hands of each student on entering the laboratory, but many students are perplexed by the peculiar, though systematic arrangement of this classic work and are at a loss to know how to begin work, what to study and where to find the information appropriate to particular cases. To aid the student in the study of Fresenius' work, and not to displace it, is one of the objects of the 'Student's Guide.'"

The methods given are stated to have been originally selected by Prof. C. F. Chandler, but were modified more or less by his assistants, Mr. Julien, Dr. Schweitzer and the author, Dr. Bolton, who have also introduced some new methods. The descriptions of many of the methods are given with commendable minuteness and clearness. There are also numerous references to other works besides Fresenius', and to articles in recent volumes of the *Chemical News*, etc.

Different chemists will, of course, entertain varied opinions as to the value of the analytical methods selected and described. This is, perhaps, always to be expected of any publication, opinion varying according to individual preferences and other circumstances. It is to be regretted, however, that some of the methods are not given in a form more suitable for strictly technical analysis. Time is a very important element in all such work, and rapidity of execution can very often be combined with sufficient exactness for the particular

object desired by the client. Inasmuch as many students in a laboratory expect afterward to engage in technical work, an appendix or second part giving such methods as are both by rapidity and accuracy especially adapted to technical and professional work of ordinary occurrence would have added greatly to the practical value of the book.

Even where the greatest possible accuracy is quite essential, as for instance in the estimation of phosphorus in iron and steel, the methods given in Fresenius', Crookes', and other works can be materially shortened with advantage and with no apparent loss of accuracy. It is true that phosphorus is a great "bone of contention" among chemists at the present day. It would, therefore, have been best to give in detail several of the different modifications of the molybdate-magnesic method now in use among various technical chemists, that the student might choose that with which he can obtain the best results.

Notwithstanding the variations described by Dr. Gibbs and others, in the composition of the phospho-molybdate precipitate excellent results have been obtained for phosphorus in steels, by a chemist of the writer's acquaintance, by weighing the yellow precipitate directly on a Gooch filter. The percentage of phosphorus in steels is so small that the variations spoken of have no appreciable influence on the result. The case is different, however, with cast iron which carries much phosphorus.

Drown's method for Silicon in iron and steel should have been given a conspicuous place in Dr. Bolton's book, and Ford's method for manganese should have been described as an important technical method. Neither of these recent improvements are even alluded to. The precipitation of zinc, from its ores, by hydrogen sulphide in an acetic acid solution should have been brought forward more prominently. It is not at all necessary to oxidize the zinc sulphide formed and precipitate as carbonate and then convert into oxide, but it may be ignited to oxide directly.

Indirect determination of both alkalies as sulphates is often more convenient than as chlorides.

In lead ores, a subject left untouched, for many purposes the ordinary fire-assay gives results as accurate as is desired by the client, inasmuch as he wishes to know especially what his own furnace will yield on a practical scale. In other cases the lead must be found gravimetrically and is best estimated for technical purposes indirectly

on two separate portions of the ore, weighing as sulphate with the gangue and then treating the one portion with hot ammonic tartrate, made strongly alkaline and subtracting the weight of the residue from the weight of the other portion.

On the subject of water analysis, Dr. Bolton would have done better by describing the albumenoid ammonia method for organic matter, instead of the method of oxidizing volumetrically by permanganate in the old way, which is now almost obsolete in this country. The indications of the latter are of very little value in determining the wholesomeness of drinking water, except in comparative tests of the same river water, like those by Dr. Tidy.

Instead of the analysis of the mineral constituents of water being given, as analysis of potable water, it would have been much more useful in a form adapted to manufacturing purposes. Much less water is required for the sample than is stated; one gallon being ample for a somewhat hard water, and two gallons for a very soft water. Satisfactory analyses have also been made to the writer's knowledge on much less quantities than these. Clarks' soap test is very little used in technical water analysis, except it might be occasionally required in analysis of water for detergent operations. It is of no particular value in ascertaining the effect of the water in producing boiler scale, which is one of the most important and frequently occurring questions in technical water analysis.

In a laboratory guide for technical students it should be stated that of two methods giving equally good results that which requires the simplest, most easily constructed, cheapest or most durable apparatus, is generally to be preferred, and this fact should be indicated in every appropriate case.

The time occupied by an average worker should be appended to each method, or the shortest time with which it has been done with accuracy.

The student should be distinctly informed which technical methods are suitable for very rapid, but only approximate results, and those which are best adapted to obtain greater accuracy with reasonable rapidity of execution.

In the foregoing remarks we do not wish to detract from the value of Dr. Bolton's book as it stands, but merely to indicate how it might be improved very materially in a future edition, so as to give it much wider usefulness.

R. H.

THE DRAWING SCHOOL.

The closing exercises of the Drawing School were held on Thursday evening, May 18th, at the Hall of the Institute, in the presence of an interested audience of members, pupils and their friends.

The exercises consisted of the exhibition of the work of the pupils, the reading of the Report of the Principal of the School and a number of addresses appropriate to the occasion.

Mr. Wm. P. Tatham, the President of the Institute, opened the exercises by stating the object of the meeting. He alluded to the solicitude with which the Institute had always fostered and encouraged the art of drawing, by maintaining its drawing school uninterruptedly for a long period of years, and expressed his great gratification at the excellent character of the work of the pupils, which was the best evidence of the thoroughness of the instruction the pupils were receiving, and of the competency of the instructors. The Secretary then read the following report of Mr. William H. Thorne, the Director of the School.

Report of the Director of the Drawing School of the Franklin Institute of Pennsylvania, for the Season of 1881 and 1882.

Notwithstanding that the present organization of the School was formed in October, 1881, with a system of instruction to determine upon and the material to provide to carry it out, with an entirely new set of students to organize and divide into classes according to their knowledge and capacities, and to furnish with the necessary materials and apparatus, and with the class-rooms to rearrange and accommodations to provide for the unexpected number of applicants; the results are gratifying.

The main feature of the School has been the teaching of such drawing as would be useful in the workshop and applicable to construction as well as to ornamentation, and thus a large part of the instruction has been devoted to the geometrical principles of drawing, but the demonstration and application of these principles have always been made to conform with the practice of our best engineers and architects, while proper manipulation and correct technicalities have been rigidly enforced; so that the student would learn how to properly use his hands and his instruments, how to give clearness and beauty to his work, and at the same time obtain a knowledge of geometrical forms

and their projections, intersections and developments, and finally, learn to make working drawings of machine or architectural constructions.

In this course, the use of copies has been almost entirely avoided, the student being required to make his drawings accurately to scale, either from free-hand sketches, or from the drawing on the blackboard by the preceptor, who spends part of his time there and part with the student in giving individual instruction and criticism. Importance is attached to the free-hand sketches of the student, and the value of this accomplishment is always kept in view. The class of exclusively free-hand drawing has been small, but the progress has been very satisfactory.

The School is divided into:

A Junior Class, under Mr. Carl Barth, who teaches the use and care of instruments, graphical plane geometry, including the conic sections and spirals, and simple projections.

An Intermediate Class, under Mr. Victor Angerer, who teaches projections, intersections and developments, and elementary descriptive geometry, using the third angle exclusively and avoiding the use of the ground line of the text books, except where necessary, and then emphasizing the fact that it is not used in working drawings. He alternates the making of working drawings of simple details with this theoretical teaching.

A Senior Mechanical Class, which I teach personally, advancing further into descriptive geometry, together with gearing and shapes and proportions of teeth, making diagrams of mechanical movements, drawing to scale, marking dimensions in a proper manner, cross-hatching, coloring, shade lining and all the conventionalities of good draughting. During the last term this class made complete working drawings of a horizontal engine, in which they took great interest, so much so that each season I shall take some standard machine as a study for the class.

An Architectural Class, under Mr. Wm. L. Price, who practically applies the principles taught in the Junior and Intermediate Classes to the making of architectural drawings. Mr. Price also teaches the Free-hand Class.

During the winter term of the season there were 120 students, divided between the Junior, Intermediate and Senior Mechanical Classes, 20 in the Architectural Class and 26 in the Free-hand Class, making a total of 166.

During the spring term there were 95 students divided between the

Junior, Intermediate and Senior Mechanical Classes, 17 in the Architectural and 11 in the Free-hand Classes, making a total of 123.

The attendance has been fair, although the proportion of absentees was greater than would be expected.

The discipline has been good and the interest of the students in their work has kept up remarkably well. Some little trouble has been experienced from the independent spirit of American youths, who occasionally differ from their preceptors as to the adaptation of certain exercises to their own particular requirements.

Another threatened trouble has been a too large congregation of students in the Library. I would suggest the withdrawal of the privilege of the Library on School evenings.

Twelve Free Scholarships from the B. H. Bartol Fund have been at our disposal during the season, nine of which were awarded at the end of the Spring Term, and the remaining three are now awarded, with the approval of the Board of Managers, to the following students for their regularity in attendance, industry and interest in their studies, and the progress shown by their work, namely, to

Joseph Leibsch, of the Free Hand Class, and to Fred. Schroeder and Martin Marshall, of the Junior Class, who, on application to the Actuary of the Institute at the beginning of the next term, October 2d, will receive their tickets.

The following students deserve honorable mention for their regularity, industry and progress:

Senior Mechanical Class.

Willis H. Groat,	J. V. Hamilton,
Chas. S. Krebs,	A. M. Hahn,
H. Frank Lennig,	G. W. Bradley,
Joseph Weiss,	W. J. Bradley,
Conrad Shaul,	R. W. Ferguson,
Reinhold E. Kuehln,	G. Whitaker,
W. P. Dallett,	John P. Casey.

Intermediate Class.

A. R. Ridgely,	Geo. D. Holt,
J. F. Braun,	Chas. S. Butz,
R. W. Champlain,	John Fauser,
Rudolph Boericke,	J. McCoy,
Thos. M. Seeds, Jr.,	Clark Dill.

JUNIOR CLASS.

Martin Marshall,	John W. Atkins,
Fred. Schroeder,	A. C. Gilbert,

Lewis Mayall.

ARCHITECTURAL CLASS.

H. E. Grau,	Wm. S. Glein,
Horace King,	Peter Motley,
Wm. S. Yerkes,	John O'Neill.

FREE HAND CLASS.

Joseph Liebsch,	John J. Breitlinger,
Richard Binder	Harry Miller,
Elwood C. Hall,	Geo. H. Merchant.

The drawings, which are exhibited for inspection, are average specimens of the work done. Some are good, some indifferent, and some decidedly bad. Much of the bad work is in consequence of the very poor instruments used by a large proportion of the students, and does not form a true index of their understanding and capabilities.

In conclusion, I wish to thank the preceptors, who have assisted me in the school, for their zeal and fidelity; also, the Committee on Instruction, Curators and Board of Managers for their willingness, promptness and liberality in providing additional accommodations, and the officers of the Institute for their hearty co-operation and assistance.

WM. H. THORNE.

May 18, 1882.

Mr. Coleman Sellers, Rev. Dr. H. J. Morton and Coleman Sellers, Jr., were then successively introduced by the President, and delivered brief addresses, which were well received.

The exercises throughout were most interesting, and the expressions of gratification by members present at the flourishing condition of the school and the progress of the pupils, were very general. W.

Franklin Institute.

HALL OF THE INSTITUTE, April 26, 1882.

Pursuant to action taken at the stated meeting of April 19th, an adjourned meeting of the Institute was held this evening at the usual hour, the President, Mr. Wm. P. Tatham, presiding. There were

present 45 members and 5 visitors. The minutes of the preceding meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers, and announced that at the last meeting of the Board 17 persons had been elected members of the Institute. He also reported, under instructions received, the following resolutions passed by the Board, to wit: "On motion of Mr. Chas. H. Banes, Chairman of Committee on Exhibitions, it was

"*Resolved*, That, in consequence of the failure to find suitable accommodations in a central locality for the purpose of a public exhibition of arts and manufactures, and of the inability of the Institute, through lack of funds, to erect a temporary structure, we deem it advisable to abandon the project of a general exhibition for the current year.

"*Resolved*, That this inability, through want of proper space accommodations to meet the public demands of the Institute, and the limited quarters now occupied by its valuable library and scientific apparatus, together with the insecure condition of the present building, from liability to destruction by fire, should prompt to further and more determined effort to obtain subscriptions for a new structure.

"*Resolved*, That, in view of the public spirit manifested by the Franklin Institute, through its prompt and valuable assistance in scientific matters of public interest, through its free lectures delivered by eminent scientists and specialists, and its large and accessible reference library, an earnest appeal be made to the citizens of Philadelphia for funds to greatly enlarge its facilities for usefulness."

An additional resolution was reported, advising certain members who had made application on April 20, 1881, to be constituted the Mechanical Engineering Section of the Franklin Institute, that, by reason of their failure to organize and report their organization to the Board within the time specified in the by-laws, the section had become extinct.

Mr. Robert Grimshaw then read the first paper of the evening, the subject being "The Influence of Pulley Diameter on the Driving Power of Belts." An abstract of Mr. Grimshaw's remarks has been referred to the Committee on Publication.

Mr. G. Morgan Eldridge read a description of his newly devised "Thermograph," an apparatus for making a continuous graphical

record of the variations of temperature. The paper, with suitable illustrations, is published in the JOURNAL for June.

In his monthly report, the Secretary, after reading the reports of the Chemical and Phonetic Short-hand Sections, announced that Mr. J. D. Rice, member of the Institute, had presented for deposit among the models of the Institute, at the request of Judge Hare, the lightning-rod points, with a section of the rod, which had been erected by Prof. Robert Hare, forty or fifty years ago, to protect his dwelling-house, which formerly stood upon the site now occupied by the new Post-office, and which was demolished some years ago to make way for the latter. This interesting relic is thus described by Prof. Hare in the edition of his Chemistry published in 1840, viz.: "I have surmounted the lightning rod, by which my mansion is protected, by 17 copper wires, pointed at one end and at the other soldered into a hole drilled in the rod, which is constructed of iron. The junction is surrounded by a globe of zinc of about two inches in diameter, above which the wires extend divergingly. The copper wires, by their association with zinc, are protected from oxidation; while their greater fusibility, as compared with the platinum point usually employed, is compensated by their number. The rod thus mounted rises about 10 feet above the apex of the roof, to the copper covering of which its lower end is soldered. The copper covering has an ample metallic connection with the pipe for carrying off the rain, and this pipe with those of the public water works, all the joints being made with screws or solder. By these means a most ample means of communication with the earth is obtained. Analogous means should be employed in the case of all lightning rods in situations where access can be had to a similar ramification of metallic pipes." After reading the above extract, the Secretary noted as an interesting fact, that the method employed at that early day by Prof. Hare corresponds in every essential particular with the best practice in vogue to-day for protecting buildings from injury by lightning. The protective influence exerted by the union of the copper points with the zinc globe, as noted by Prof. Hare, was alluded to as a fact of special interest, the condition of the points after nearly half a century's exposure to atmospheric influences showing a remarkable state of preservation, being now almost as sharp as when the rod was first put up. Accompanying the

relic, Mr. Rice presented for comparison a modern copper rod--a twisted cable of a number of copper wires without points, with the ends frayed out in brush-like form.

The Secretary read also a long communication from Mr. D. T. Lawson, of Wellsville, Ohio, describing the details of certain experiments which he had caused to be made to demonstrate the correctness of his views, that a steam boiler can be exploded by the sudden removal of a considerable volume of steam from the boiler, causing the sudden bursting into steam of the superheated water; and describing, also, a preventive which he had devised to guard against this form of danger, consisting of an arched perforated diaphragm fixed horizontally near the water-line inside of the boiler, designed to regulate the rapidity of the abstraction of steam from the boiler.

Among the mechanical and technical novelties exhibited, the following are of sufficient importance to warrant special mention, viz.: Bailey's astral lantern, an ingenious device for showing maps and furnishing a "directory" of the heavens; an "accelerating" shot, invented by Thomas Shaw; Jenks' duplex injector; a full suite of products of asbestos from the H. W. Johns Manufacturing Company, and of mineral wool from the U. S. Mineral Wool Company; the Perret furnace for burning refuse fuel, shown by Ostheimer Bros.; Mestern's water-spray ventilating apparatus; a driving-wheel for sewing machines, turning on steel ball bearings with greatly reduced friction, exhibited by the Hartford Sewing Machine Company; Arnold's steaming apparatus for cooking; a minute egg glass, with an alarm bell attachment, for use in boiling eggs, and Herren's milk tester. This has a glass disk, with sections colored to represent different qualities of milk. A drop of the milk to be tested is pressed under the clear centre space of the glass disk into a thin film, and its quality judged by comparison with the standard shades of color on the edges of the disk. The two latter inventions were exhibited by Wm. M. McAllister.

Mr. William B. Cooper then followed with a description of a new apparatus for increasing the dynamic effect of the pulsations of diaphragms, etc., which he termed the "phonodynamograph." A model of the apparatus was shown at the close of the meeting, and an abstract of the speaker's remarks appears in the JOURNAL.

The meeting thereupon adjourned.

WILLIAM H. WAHL, *Secretary.*

HALL OF THE INSTITUTE, May 17, 1882.

The meeting was called to order at the usual hour, with the President, Mr. Wm. P. Tatham, in the chair.

There were present 125 members and 17 visitors.

On the reading of the minutes of the meeting of April 26th, the Actuary called attention to the fact that the number of members reported as having been elected at the previous meeting of the Board of Managers should be 17, instead of 21, as read; and with this correction the minutes were approved.

The Actuary submitted the minutes of the Board of Managers for May, and reported that at that meeting 21 persons had been elected members.

Mr. C. Colné, the Secretary of the American branch of the Interoceanic Canal Company, read an interesting paper giving important details concerning the engineering features and commercial aspects of the De Lesseps enterprise at Panama, together with a statement of the present condition of the work on the Isthmus. He deprecated the opposition to the enterprise that had been manifested in some of the daily journals, alleging that this hostility emanated from parties interested in rival projects and asserting that the company would demonstrate that it was not in any sense anti-American, but was, on the contrary, deserving of the full sympathy and support of the American people.

Remarks upon the paper were made by Messrs. Hector Orr and J. W. Nystrom.

The paper has been referred to the Committee on Publication.

At the close of the discussion on the subject, on the motion of Mr. C. Chabot, the thanks of the meeting were tendered to Mr. Colné for his interesting and valuable communication.

Mr. George S. Strong next described his improved feed-water heater and purifier and filter, illustrating the same with the aid of the lantern, and by a specimen of the heater. An abstract of the description has been prepared for the JOURNAL.

Mr. Louis S. Spellier followed with a paper on Electric Clocks and Time Telegraphs, describing certain improvements and simplifications in such apparatus, which he had devised. The paper was well illustrated, and has been referred to the Committee on Publication.

Mr. Wm. B. Cooper then made some remarks, explaining more fully than he had been prepared to do at the previous meeting, his

method of increasing the dynamic effect of the pulsations of diaphragms. Mr. Cooper's remarks have likewise been referred for publication.

The Secretary's report, which was abbreviated on account of the lateness of the hour, included the report of the Chemical Section and a brief description of mechanical and technical novelties which were on exhibition. Of these the following are worthy of special mention: A very complete and representative exhibit of graphite and products manufactured therefrom, made by the Joseph Dixon Crucible Company of Jersey City, N. J.

A number of improved tubular lanterns shown by Mr. J. H. Irwin, of Morton, Delaware co., Pa.

Cooke's Illuminating Oiler, an oiler and lantern combined in compact form; a very convenient device for using in the dark in and about machinery, as the lamp is so arranged that it throws its rays directly across the nozzle of the oiler to the place desired. Shown by the H. B. Smith Manufacturing Co., Philadelphia.

A number of fine specimens of phototypes, shown by Mr. F. Gutekunst, of Philadelphia, and a fire escape ladder shown by Wm. G. Selzer & Co., Philadelphia.

Prof. E. J. Houston then addressed the meeting at some length, calling attention to the dangerous character of the sewage emptied into the Schuylkill river near the eastern end of Girard avenue bridge, close to the Spring Garden Water Works, and within less than a mile of the Fairmount Works.

After remarks by Mr. W. B. Cooper, C. Chabot and G. Morgan Eldridge, it was, on motion, resolved, that the President be requested to appoint a committee to give expression to the views of the Franklin Institute concerning the pollution of the waters of the Schuylkill from the entrance of sewage near the eastern end of the Girard avenue bridge, and to report their conclusions, with such recommendations as they felt called on to make, to the next meeting of the Institute.

Tre President, in pursuance of the above resolution, named the following committee, viz.: Prof. E. J. Houston (chairman), Frederick Graff and Reuben Haines.

The meeting was then, on motion, adjourned.

William H. Wahl, *Secretary.*

Erratum.—Chase. Radio-dynamics, etc., page 437, line 4 from end of article, for 961·[11]83, read 961·″83.